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A National Compendium of Freshwater Fish and Water Temperature Data. Volume I: Data Management Techniques Output Examples and Limitations

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A National Compendium of Freshwater Fish and Water Temperature Data

Volume I
Data Management Techniques, Output Examples and Limitations

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The present study resulted in the compilation of a computer data base containing historical fish distribution data with accompanying water temperature data from about 1930-1972 for over 300 species of freshwater fish from 574 locations in the United States and provides the first nationwide compendium that describes freshwater fish population habitats in relation to water temperature regimens. Data collected from many unrelated sources were edited, formatted and assembled into a meaningful presentation. The transformation of the encoded data into magnetic characters on a computer data tape was accomplished with a Honeywell 702 Keytape machine. Computer programs developed were written in the FORTRAN IV language and implemented on the Univac 1108 computer system. The present data system was implemented primarily as a computer data storage and retrieval method. As such, the computer programs were largely designed to format, sort, store and recall selected records, or groupings of data.

For analyzing data, computer programs were developed for: (1) determining the frequency of occurrence of certain types and classes of data; (2) determining the number of fish temperature data sets (fish present at the same time and place water temperatures were taken) by: a) major and minor river basins, b) thermal characteristics, c) sampling method, and d) temperature and fish catching equipment type; (3) compiling fish species data and correlating these with water-temperature records; (4) producing tables with minimum, maximum and mean temperatures with corresponding fish counts; and (5) producing cumulative percentiles of weekly water temperatures for each fish species. Suggestions as to possible uses for the data and programs are given. Also included are some case example studies.

A section is included describing the limitations of the encoded fish and temperature data and a critique of the: (1) data quality, (2) environmental quality, (3) quality of the work performed, (4) materials and methods used to collect fish and temperature data, and (5) data reporting and analysis.

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A NATIONAL COMPENDIUM
OF
FRESHWATER FISH AND WATER TEMPERATURE DATA

Volume I

Data Management Techniques, Output Examples and Limitations

by

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FOREWORD

Our nation's fresh waters are vital for all animals and plants, yet our diverse uses of water -- for recreation, food, energy, transportation, and industry -- physically and chemically alter lakes, river, and streams. Such alterations threaten terrestrial organisms, as well as those living in water. The Environmental Research Laboratory in Duluth, Minnesota, develops methods, conducts laboratory and field studies, and extrapolates research findings

-- to determine how physical and chemical pollution affects aquatic life;

-- to assess the effects of ecosystems on pollutants;

-- to predict effects of pollutants on large lakes through use of models; and

-- to measure bioaccumulation of pollutants in aquatic organisms that are consumed by other animals, including man.

This study was undertaken to provide an independent data base describing ambient temperature regimens inhabited by various freshwater fish populations throughout the Continental United States. A national survey was conducted to compile and collate information on freshwater fish and water temperature records collected independently by various state and federal agencies, educational institutions and private enterprise. This report (Volume I) describes the data management methods and limitations with descriptions of computer programs used in sorting and evaluating data. Numerous examples of some possible applications to contemporary problems in water quality and fishery management are discussed. Volume II describes thermal requirements of thirty freshwater fish based on laboratory and field data and includes a critique of the sources of variation. An analysis of thermal criteria and temperatures inhabited by freshwater fish species are evaluated in Volume III from a synthesis of field and laboratory data.

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PREFACE

The work for this report was performed by staff members of: (1) The Environmental Sciences Department of Plessey Environmental Systems of San Diego, California (formerly the Bissett-Berman Corporation) with programming and computer services supplied under subcontract by Eco-Logic, Inc. of San Diego; (2) Eco-Logic Systems Analysts, Inc. of San Diego, California; (3) Systems, Science and Software of La Jolla, California; and (4) the U.S. Environmental Protection Agency, Duluth, Minnesota

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Bissett-Berman Corporation. 1970. Historical Review of Temperature as Related to Fish Populations. Attachment II. Technical Proposal. Federal Water Quality Administration, Duluth, MN.

Bissett-Berman Corporation. 1971. Historical Review of Temperature as Related to Fish Populations. Interim Report - Phase I. U.S. Environmental Protection Agency, Duluth, MN. Contract 14-12-941.

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For analyzing data, computer programs were developed for: (1) determining the frequency of occurrence of certain types and classes of data; (2) determining the number of fish temperature data sets (fish present at the same time and place water temperatures were taken) by: a) major and minor river basins, b) thermal characteristics, c) sampling method, and d) temperature and fish catching equipment type; (3) compiling fish species data and correlating these with water temperature records; (4) producing tables with minimum, maximum and mean temperatures with corresponding fish counts; and (5) producing cumulative percentiles of weekly water temperatures for each fish species. Suggestions as to possible uses for the data and programs are given. Also included are some case example studies.

A section is included describing the limitations of the encoded fish and temperature data and a critique of the: (1) data quality, (2) environmental quality, (3) quality of the work performed, (4) materials and methods used to collect fish and temperature data, and (5) data reporting and analysis.

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SECTION 1

INTRODUCTION

Altered thermal regimes of our nation's waterways originate from numerous man-made heat sources such as power plants, industrial, and municipal effluents as well as impoundments and logging practices. The steadily increasing "thermal modification" of our nation's lakes and streams from these sources has been a subject of increasing concern for a number of years, especially in terms of ecological effects on the aquatic environment. In view of this concern, a clear separation of the phenomena of normal cultural and natural warming of fresh water bodies from heat caused by man must be made, as temperature is perhaps the single most influencial factor governing the distribution, behavior, growth and reproduction of freshwater fishes. The temperature of surface waters of the United States vary from 32 F (0 C) to over 100 F (37.8 C) as a function of geographical location. Factors influencing water temperature include latitude, altitude, seasonal and diel cycles, volume and duration of flows, depth, substrate type, overhead canopy, turbidity, etc. These factors are indeed so numerous that is is seldom that two nearby bodies of water exhibit the same thermal characteristics or species composition. Extensive bibliographies have been compiled and detailed reviews of the relationship of temperature to aquatic life have been published (American Society of Civil Engineer 1967; Brett 1960; Kennedy and Mihursky 1967; Raney 1967; U.S. Department of the Interior 1967; Wartz and Penn 1965; Brown 1974; Coutant and Talmage 1975; also Coutant and others in years from 1968 through 1977). In order to effectively establish meaningful water quality criteria regarding thermal discharges into fresh water streams, rivers, and lakes, requirements clearly exist for reliable data on both the natural thermal characteristics of these bodies of water and for data on the relationship of temperature to endemic biota.

In the past, federal, state and local government agencies, universities, private research institutions and industrial organizations have all played a role in the collection of large quantities of data in connection with investigations regarding various aspects of fresh water fishes. These programs have usually been in response to needs dictated by problems associated with the conservation of fisheries resulting from overfishing and the environmental effects of water pollution caused by stream diversion programs, urban development, and industrial and municipal waste discharges. The present study was undertaken in an attempt to bring this information together in a computer format and make it available for problem solving.

The primary objective of this National Compendium of Freshwater Fish and Water Temperature Data Study was to assemble and collate a computer and information management system data base containing historical water temperature records and fish population records for major lakes and streams in the continental United States. The computer data base was designed to provide: (1) an independent basis for describing temperature regimens inhabited by freshwater fish to assist in developing and evaluating temperature criteria, (2) a procedure to evaluate changes or stability of fish populations, (3) a procedure to identify warming or cooling trends in bodies of water, (4) an indication of the past and present geographical distribution of fishes, (5) and provide a scientific basis for fish management. The data base was designed so that it may be expanded and also include other water quality parameters such as dissolved oxygen, alkalinity, hardness, pH, heavy metals, organic compounds, etc. In addition, the data base may be used in conjunction with other data bases containing biological, physical and chemical measurements.

The scope of this study included the development of techniques for the collection, processing, and reduction of the resulting fish population and water temperature data to a computer-compatible form to facilitate correlation and analysis of the results. The study was conceived to be a full-scale national effort covering the United States, including Alaska, but excluding Hawaii. The basic study was conducted during 1970-72. Information in the data base includes data collected through 1972. Additional data management efforts were completed during 1973-75.

This report (Volume I) describes an independent data base containing ambient temperature regimes inhabited by various fish populations. It is intended to present a summary of information encoded, computer programs now available for analyzing data, limitations of the data base and some examples of how the data might be used. It is hoped that potential users of the data base can gain some insight as to how they may use it to solve a multiplicity of problems. It is further hoped that the information encoded will be used and updated to solve water quality problems, chronicle changes (both natural and man induced) in fish species and population dynamics, and provide a rational basis for controlling heat discharges which will protect aquatic life, yet not lead to energy waste to construct cooling devices where they are not needed.

Volume II of the study entitled "Development of Thermal Criteria and Some Sources of Variation" describes thermal requirements for thirty freshwater fish species based primarily upon laboratory data and natural history observations. The ultimate upper incipient lethal temperature, growth optimum, final temperature preferendum, physiological optimum, and reproductive requirements are compiled in criteria tables for each species. In addition, important experimental variables are summarized to identify sources of variation in the laboratory data base. Bioassay responses and endpoints are defined and some test conditions contributing to variation in the data base is discussed. Existing thermal criteria have been expanded upon by review of the literature published through 1978 and includes a bibliography on over 700 references.

Volume III of the study entitled "Analysis of Thermal Criteria and Temperature Regimes Supporting Stream Fish Populations" provides an evaluation and synthesis of the field and laboratory data base found in Volumes I and

II, respectively. Thermal requirements of temperate climate fishes are classified into three groups (cold-water, cool-water, and warm-water fishes); the thermal limits of each are defined. Specific adaptations to the seasonal temperature cycle are described for thirty species. The role of temperature and day length on fish reproductive cycles is reviewed using new knowledge from both experimental lab studies and natural history observations. Particular importance is placed on studies describing modification in the reproductive cycles for species introduced beyond their indigenous range, including subtropical and tropical climates or subject to extreme thermal modifications. A generalized model of the seasonal temperature envelope and its relationship to thermal criteria is discussed with recommendations for future criteria development.

SECTION 2

SUMMARY AND CONCLUSIONS

The present study has resulted in the compilation of a computer data base containing historical fish-temperature data for over 300 species of freshwater fish from 574 locations in the United States.

The present study results provide the first nationwide compendium describing thermal limits to distribution for various freshwater fish populations. They also chronicle those changes already observed in existing records and provide an independent data base for the establishment and evaluation of state and federal thermal water quality criteria.

The computer data base contains historical water temperature and fish population records from about 1930 up to 1972 for lakes and streams in the United States excluding Hawaii.

A considerable amount of historical data was available on fish populations and lake and stream water temperatures. However, it was an exception rather than the rule to find these two types of data collected simultaneously by the same agency. Therefore, the initial efforts of this study were to piece together by location and time period the two types of data which had been collected from the various sources supplying the information.

Data collected from many unrelated sources were edited, formatted and assembled into a meaningful presentation. The transformation of the encoded data into magnetic characters on a computer data tape was accomplished with a Honeywell 702 Keytape machine. Computer programs developed were written in the FORTRAN IV language and implemented on the Univac 1108 computer system.

Although conceived with growth and change in mind, the present data system was implemented primarily as a data storage and retrieval method. As such, the computer programs were largely designed to format, sort, store and recall selected records, or groupings of data. However, several optional use sequences available to the user may be employed to effect editing, perform selected station studies, do geographic or environmental area studies, and obtain graphic presentations of single or composite fish and temperature station(s) records. Compatibility of the fish-temperature data with EPA's STORET and BIO-STORET system and other computer systems is assured through the indexing of selected data stations by latitude and longitude coordinates.

For analyzing data, computer programs were developed for: (1) determining the frequency of occurrence of certain types and classes of data; (2) determining the number of fish temperature data sets by: a) major and minor river basins, b) thermal characteristics and sampling method and c) temperature and fish catching equipment type; (3) compiling selected fish species data and correlating these with fish-temperature records; (4) producing tables with minimum, maximum and mean temperatures with corresponding fish counts; and (5) producing cumulative percentiles of weekly temperatures for each species.

Computer graphic capabilities of encoded data include: (1) plots displaying weekly and monthly minimum, maximum and mean temperatures for one or more species for each station and year; (2) weekly or monthly minimum, maximum and mean temperature for a given fish species for selected stations, for several years at one station or for several stations and many years; (3) fish population histograms showing as many as twenty-six species in order of abundance for a given station and year or for a given station and several years; (4) all temperatures (minimum, maximum and mean) at which a given species is present for all stations and years where there are matching fish-temperature data sets.

Some case example studies are included to suggest ways in which the data might be used. These include a discussion of: (1) temperature changes on the Columbia River at Bonneville Dam where fish were counted in a ladder; (2) temperature changes as a result of dam construction on the Green River where fish were counted from electro-fishing and gill netting; (3) temperature on the Trinity River as effected by dam construction where fish were counted at a fish trapping facility; (4) relatively stable temperatures on Sagehen Creek where fish were counted by draining the stream; (5) temperature changes on the Mississippi from its head waters to its mouth with resulting changes in species composition where fish were counted using numerous types of fish sampling equipment; and (6) distribution and temperature regimens for channel catfish.

A section is included describing in detail the limitations of the encoded fish and temperature data. Also included is a critique of the: (1) data quality, (2) environmental quality, (3) quality of the work performed (4) materials and methods used to collect fish and temperature data, and (5) data reporting and analysis.

SECTION 3

RECOMMENDATIONS

It is recommended that the Federal Government initiate planning efforts for the establishment of uniform standards of accuracy and sampling frequency for stream, reservoir, and lake temperature measurements for the purpose of providing a common base for discussion and analysis of thermal modification of water quality. The U.S. Environmental Protection Agency, in collaboration with the U.S. Geological Survey should sponsor a thorough review of water temperature measurement techniques and systems. A recommended list of standard instruments having approved ranges of accuracy should be prepared and published. Such a list should be included within the technical specifications and requirement portions of all Federally-sponsored grants and contracts in fisheries and water quality research and management programs.

It is recommended that cooperative efforts be initiated between the Environmental Protection Agency, the U.S. Bureau of Sport Fisheries and Wildlife, and individual state Fish and Game Commissions to establish a nationwide observational network and standard procedures for sampling freshwater fish populations. The allocation of additional federal funds to the individual states from the Dingell-Johnson program (Federal Aid in Fish Restoration Act) should be evaluated as a means of inducement for implementing any such network.

The professional fisheries research organizations (e.g., the American Fisheries Society; the Wildlife Society; the American Institute of Fishery Research Biologist; and others) should be encouraged to study fish population sampling techniques and problems thoroughly. They should recommend standard types of gear for prescribed species or species groups in different types of habitat. Standard mesh sizes, fishing techniques, and sampling intervals should be prescribed or established wherever possible. Development of standard reporting units, terminology, and formats also should be encouraged at the national level.

Routine measurements of water quality parameters at the time of fish population census should be encouraged. Development and standardization of the necessary sensor technology to take these measurements should be strongly supported. Professional organizations as well as government agencies should be encouraged to study and recommend those water quality parameters that should be reported regularly.

A national repository should be established and supported to house all fish population census and habitat quality information. State and federal agencies should develop standard summary reporting formats to ensure that the necessary data are forwarded to the repository upon completion of the work. All Federal Aid projects should be required by specific terms of the contract to contribute such information directly to the repository. The repository should engage in a continuous data quality control program, and bring discrepancies to the attention of the contributor when necessary.

The federal agencies involved in environmental monitoring, water resources management, fisheries, and recreation should coordinate program planning and committment of resources to ensure maintenance of soundly based programs serving the public interest. Formation of river basin commissions and other technical coordination bodies should be fostered at the regional, state, and local jurisdictional levels.

Agencies at all levels should prepare periodic "state of the environment" reports, in which significant changes observed in the preceding interval are chronicled and evaluated. These reports should be issued on an annual basis for purposes of compilation and interpretation at a later time.

It is recommended that the present study data base be further evaluated in order to develop an atlas of the seasonal occurrence and geographical distribution of the species catalogued during this study. Essentially, this effort would produce a nationwide zoogeography of freshwater fishes.

Documents collected during this study should be utilized to expand the present data base in terms of supplying additional information regarding physical and chemical properties of the various water bodies. These data would provide a more comprehensive base from which known shifts in species distribution and abundance could be evaluated.

It is further recommended that the present data base be brought up to date and that a mechanism for keeping it current be adopted.

SECTION 4

DATA MANAGEMENT

This section is devoted to the description of the methodology conceived for or evolving from the present study. This methodology can be presented in terms of a data management concept since a predominance of the work defined for the study has involved the essential elements of data management, e.g., data collection, data encoding (collation), computer processing, and presentation of output. These elements will be discussed in the subsequent text and will include a brief description of the major computer routines developed to facilitate the storing, retrieval and analysis of the collected data. Where appropriate, ancillary data and descriptive materials have been included as appendices to this report.

DATA MANAGEMENT DESIGN CONCEPT

Perhaps one of the most difficult and complex aspects surrounding the development of software for the present study was the basic design and implementation of a data base management system. The uncertainty of the data base use requirements certainly contributed to the design problems, but more than this, the great variability in the collected data, methods, reports, and instrumentation imposed a constant pressure on the Fish-Temperature Data Management System (FTDMS) to be flexible and general. Unfortunately, the use of any such system is not general. Rather, it is a function of specific user demands. The subsequent dilemna resulted in a design compromise. The design goal of this system was to satisfy a major portion of both these requirements.

The basic flow of logic inherent in the philosophy of the FTDMS is shown in Figure 1. The three types of data were defined as station data, fisheries data, and temperature data. In general, the data were encoded in the data base independently in sets. A set consisted of (1) station data and fish data, (2) station data and temperature data, or (3) station, fish, and temperature data. These data classifications will be discussed in detail in the subsequent text, but it is important to note that the three classes of data usually were collected and encoded separately. For the most part, the matching of fish data to chronologically corresponding temperature data sets was accomplished by analytical computer programs which organized the data by river-basin and species categories.

A set of computer programs was developed to store the raw data after it was formatted, sorted, and edited. This process resulted in stream data and lake data. The stream data relates water temperatures to indigenous fish in moving water (rivers, creeks, canals, etc.) and the lake data relates

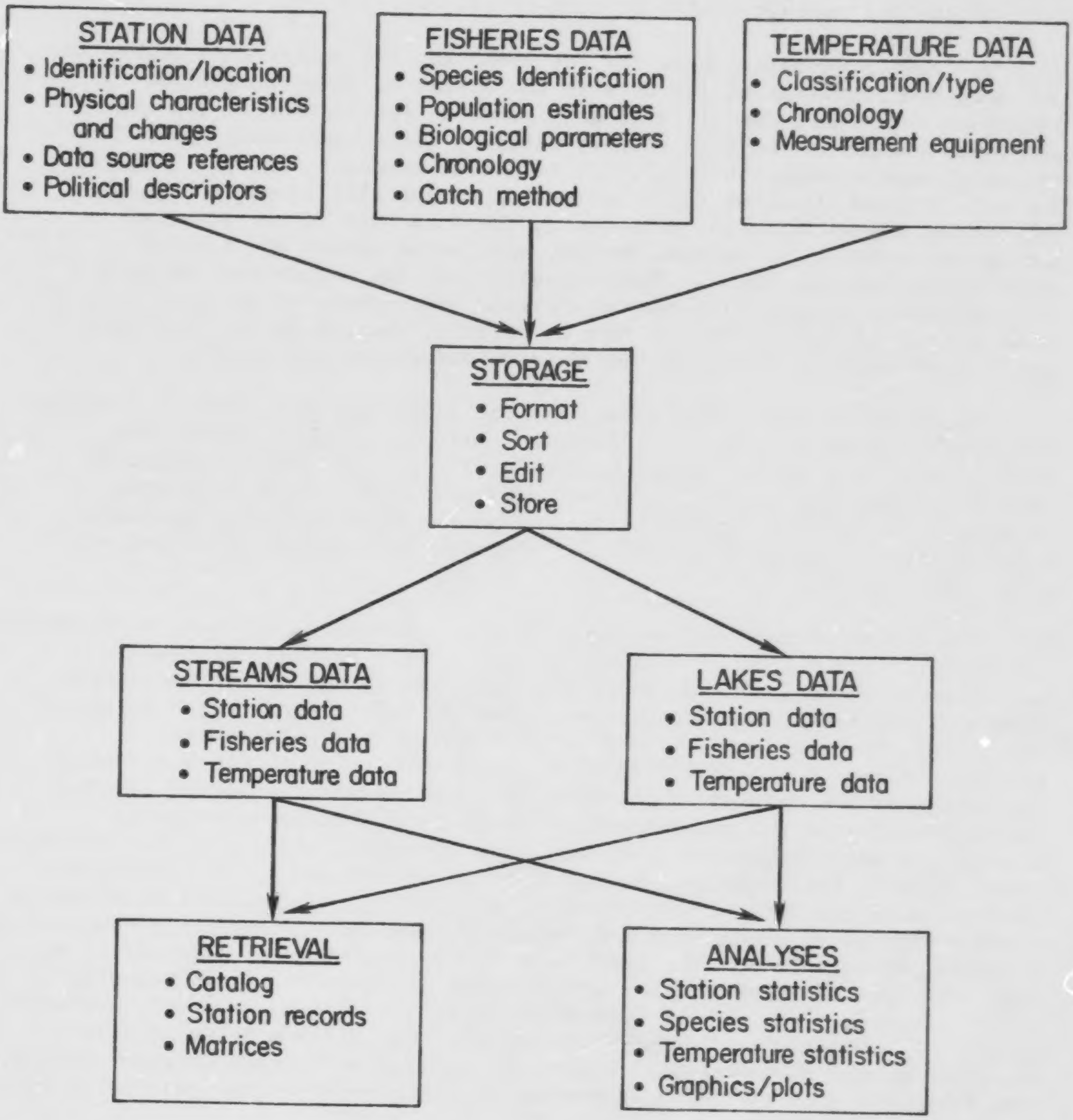
STATION DATA
• Identification/location
• Physical characteristics and changes
• Data source references
• Political descriptors
FISHERIES DATA
• Species Identification
• Population estimates
• Biological parameters
• Chronology
• Catch method
TEMPERATURE DATA
• Classification/type
• Chronology
• Measurement equipment
STORAGE
• Format
• Sort
• Edit
• Store
STREAMS DATA
• Station data
• Fisheries data
• Temperature data
LAKES DATA
• Station data
• Fisheries data
• Temperature data
RETRIEVAL
• Catalog
• Station records
• Matrices
ANALYSES
• Station statistics
• Species statistics
• Temperature statistics
• Graphics/plots

Figure 1. Data management concept.

fish to impounded waters (lakes, reservoirs, ponds, etc.). For aquatic systems such as the Mississippi River which is a series of "pools" connected by the river, the entire system was treated as a stream category although, perhaps, some of the data should reside in both categories.

The next processing phase for the FTDMS was the design of a method for the selected retrieval of the data in the stream or lake categories. The retrieval logic includes (1) a library catalog type listing of all stations and fish species in the data base by category (lake or stream) and reference volume (computer magnetic tape), (2) formatted computer listing of select (or all) station data, or (3) a variety of parametrically-paired matrices describing the quantitative contents on the data base in the selected parameters (species vs capture method, species vs number and type of temperature records, etc.). This capability of the system was envisioned as a necessary prerequisite to any analysis since users of the data base will need to know if the particular data of interest resides in the data base in the desired station (location) and species categories and quantities.

The final phase of development for the FTDMS was the coding of a set of computer programs with which to compile stations, species, temperature statistics, and graphical presentations of these data. While certainly not exhaustive, the set of analytical programs issuing from this study represents an initial capability and allows the user to derive essential conclusions and graphics suitable for inclusion in reports, articles, or other publications.

The design of the Data Management System proceeded in steps, or iterations, throughout the duration of this project, primarily because the study requirements themselves changed as knowledge was gained during successive levels of progress. One of the most demanding requirements which persisted throughout the study was the need for the system to reconcile the inconsistencies in the collected data. This problem had a major effect on the design of the data encoding sheets and the attendant computer programs. The variability in the collected fish-temperature data is principally because the data originated from many diverse sources which were not necessarily interrelated. Consequently, some of the summary statistics for particular categories in the data base are numbers representing the results of unrelated field experiments, nonuniform sampling procedures and incomplete documentation. An important example of this problem is in the reporting of quantity of fish sampled. Some of these samples are in terms of "species per stream-mile", or "per creel". Some are in "pounds per acre", or "fish per acre", and still others are presented as "percent of sample". The obvious difficulty in correlating such varied units resulted in a computer storage category called, fish "count". This is the sump into which all quantifying estimators of fish populations are stored.

Any inferences made from such numerics need to be cautious and qualified. In order to correct this frailty in the collected data, a correlation analysis needs to be performed to determine weighting factors or summing techniques which yield meaningful statistics. Since this effort was outside the scope of the development of the data management system, the numbers in "count" have been used for this report, however, these results need to be qualified in the context of their probable relative inconsistencies. There are other examples of this type of data irrelevance which ultimately will be corrected only after a national data reporting format has been implemented.

Such problems have required the design of a data management system which is flexible and amenable to growth or change. This versatility is provided by the present system in four ways: (1) The programming language and computer environment were selected to provide a nearly universal use. (2) The system was conceived to be user oriented. The computer logic provides for recalling, inspecting, and editing stored records. Through the use of various matrix routines, it allows rapid assessment of selected dependent and independent variables in the data base which can ultimately be presented by means of computer graphic presentations to give the user a visible summary of the selected data. (3) A modular construction of all computer programs was made to provide convenient building blocks for future use (different use sequences, analytic models, etc.), and (4) the individual data records for fish and temperature data are in a format (80-column cards) which can be extended to other parameters of interest (water chemistry parameters, turbidity, etc.).

Although conceived with growth and change in mind, the present system was implemented primarily as a data storage and retrieval method. As such, the computer programs are largely designed to format, sort, store, and recall selected records, or groupings of data. However, several optional use sequences available to the user can be employed to effect editing, perform selected station studies, carry out geographic or environmental area studies, and give graphic presentations of single or composite fish and temperature station(s) records. They can also be used in conjunction with the U.S.E.P.A. computer net to expand the data base through utilization of selected data of records stored on that system. Compatability of the fish-temperature data base with EPA's STORET, BIOSTORET, and other systems is assured through the indexing of selected data stations by latitude and longitude coordinates. Hence, any pertinent data incorporated into these systems by other federal agencies can be recalled and processed for inclusion into the FTDMS.

DATA COLLECTION

The ultimate success of the fish-temperature study depended largely on developing adequate data collection procedures. The first stage of the data collection program consisted of an extensive telephone survey of the particular geographical region under consideration to establish field survey contacts. The second stage consisted of a follow-up mailing program to further acquaint the established contacts with the purpose of the study prior to actually contacting them in the field. The third stage of the data collection portion of the survey consisted of visits to individuals in various organizations to acquire fish-temperature data. In order to provide a clear perspective of the work involved in successfully conducting a data collection program of this nature, each of the foregoing survey procedures is described in the following paragraphs. A major factor in the overall success of this study was the excellent cooperation and assistance extended from most organizations and individuals contacted. In addition to making originals and copies of data available on site, several individuals assisted in the task of data collection by gathering the data together themselves, and mailing it to project personnel.

The initial step in the telephone survey was to establish liaison with major federal agencies. The focal points for achieving this were the Regional Offices of the Environmental Protection Agency. With the assistance of the EPA project coordinator, it was formally agreed that each of the Regional Offices would assist the study team by providing survey contacts and acting as liaison between the numerous governmental agencies operating within their administrative region.

Based on both the contacts supplied by the EPA Regional Offices and others developed by the study staff, the initial telephone survey was conducted on a state-by-state basis. Each call was logged on a telephone contact sheet for record-keeping purposes. The starting point with most states was through the state fish and game agencies where the majority of all freshwater fish data were believed to be held.

Initial study contacts typically produced names of several knowledgeable individuals within universities and federal and state agencies and organizations such as the U.S. Bureau of Sport Fisheries and Wildlife (BSF&W), U.S. Army Corps of Engineers (ACE), U.S. Bureau of Land Management (BLM), U.S. Geological Survey (USGS), state water quality agencies, Cooperative Fishery Units (BSF&W), and public utilities. The telephone survey for each geographical region was concluded when it became apparent that contacts were referring the study staff to individuals who had already been contacted.

Where there was any indication of available data for the study, a letter explaining our specific requirements and a copy of a study abstract were mailed to the individual. The utilization of a study abstract as a tool in the survey served two essential purposes. The first of these was to provide specific information about the study to field contacts prior to our arrival. This procedure often resulted in considerable time saving as the individual contacted was usually able to assist the study team much more efficiently as a result of his being more aware of our specific needs. The second purpose of the study abstract was to acquaint as many organizations and individuals as possible that a national fish-temperature study was in progress. This was also accomplished by mailing out the abstract to a large number of "trade magazines" and including it in newsletters produced by various organizations.

Upon completion of the telephone survey, interviews were scheduled with individuals located in each of the states to be visited. This task was divided among members of the study staff and was conducted over a period of seventeen months. The staff members interviewed and obtained data from as few as one to as many as eight individuals from a given organization. Originally, it was planned to utilize a questionaire to transcribe the fish and temperature data in the field from the original files held by the various individuals. Ideally, this would have facilitated the computer encoding process; however, because of the diverse types of fish and temperature data formats encountered this approach was abandoned early in the study as impractical.

Prior to embarking on the field surveys, each staff member was required to thoroughly familiarize himself with the existing water resource programs in the geographic area being visited. This facilitated questioning the contact as to the availability of specific types of investigations known to be associated with water resources (i.e., environmental impact surveys on impounded rivers or routine water quality monitoring of a particular river drainage). Knowledge of the types of data obtained from other areas previously surveyed was also helpful, as reference to them often triggered a response from a new contact. For example, one could solicit fish data for a particular location where it had been previously determined from personnel in the U.S. Geological Survey that a good series of temperature records were available. Likewise, the mention of a particularly good set of fish data to a water resource agency often led to the disclosure of a compatible temperature set. Additionally, contacts were more willing to cooperate in releasing their information when project personnel limited their interview to specific questions.

In summary, by employing comprehensive telephone, mail, and field survey techniques, a computer data base of largely unpublished fish-temperature data in excess of 570 stations was compiled. During the course of the study, 790 individuals were contacted by telephone, letter, or personal interview from 589 separate federal and state agencies and other organizations in 251 U.S. cities -- a state-by-state tabulation of this coverage is shown in Table 1.

DATA ENCODING PROCEDURES

The collected data were screened and qualified as to importance in the study. The qualified documents were then assigned an "accession number" and remitted to the fish-temperature library. A summary of the data thus collected includes the following:

I. Inclusive dates for which temperature and fish population data apply for each of 50 species (Table 2) selected because of their commercial or recreational importance as well as other species found in Appendix A.

II. Source of information for:

  A. Temperature
  B. Fish data

III. Location:

  A. State
  B. County
  C. River, reservoir, or lake (on reservoir or lake, specify exact location)
  D. Nearest highway and town or river mile
  E. Elevation
  F. Isotherm

TABLE I. TOTAL CONTACTS INITIATED

State	Cities	Agencies	Individuals
Alabama	4	10	11
Alaska	4	8	9
Arizona	4	11	15
Arkansas	4	8	14
California	17	41	53
Colorado	3	12	11
Connecticut	3	5	7
Delaware	3	6	8
Florida	9	14	18
Georgia	4	13	22
Idaho	2	8	12
Illinois	8	20	28
Indiana	4	7	8
Iowa	6	13	15
Kansas	5	9	14
Kentucky	6	8	9
Louisiana	4	13	22
Maine	8	13	16
Maryland	3	4	6
Massachusetts	3	9	11
Michigan	5	15	26
Minnesota	6	15	29
Mississippi	5	11	13
Missouri	4	8	11
Montana	6	15	21
Nebraska	4	10	12
Nevada	7	16	24
New Hampshire	3	6	8
New Jersey	6	10	10
New Mexico	2	10	7
New York	9	19	24
North Carolina	2	9	10
North Dakota	2	10	13
Ohio	4	10	14
Oklahoma	5	13	12
Oregon	4	21	34
Pennsylvania	7	12	10
Rhode Island	2	4	4
South Carolina	2	6	7
South Dakota	6	10	11
Tennessee	6	10	14
Texas	14	28	34
Utah	3	7	19
Vermont	2	6	8
Virginia	4	8	7
Washington	9	20	29
West Virginia	4	7	8
Wisconsin	9	23	29
Wyoming	3	9	8
Washington, D.C. (Arlington)	2	9	24
Total	251	589	790

TABLE 2. LIST OF THE 50 FISH SPECIES SPECIFIED FOR ANALYSIS

Common name	Scientific name
White sturgeon	*Acipenser transmontanus*
Alewife	*Alosa pseudoharengus*
Gizzard shad	*Dorosoma cepedianum*
Threadfin shad	*Dorosoma petenense*
Lake whitefish	*Coregonus clupeaformis*
Pink salmon	*Oncorhynchus gorbuscha*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Sockeye salmon	*Oncorhynchus nerka*
Chinook salmon	*Oncorhynchus tshawytscha*
Mountain whitefish	*Prosopium williamsoni*
Cutthroat trout	*Salmo clarki*
Rainbow trout	*Salmo gairdneri*
Atlantic salmon	*Salmo salar*
Brown trout	*Salmo trutta*
Brook trout	*Salvelinus fontinalis*
Lake trout	*Salvelinus namaycush*
American smelt	*Osmerus mordax*
Chain pickerel	*Esox niger*
Northern pike	*Esox lucius*
Muskellunge	*Esox masquinongy*
Carp	*Cyprinus carpio*
Fathead minnow	*Pimephales promelas*
Longnose sucker	*Catostomus catostomus*
White sucker	*Catostomus commersoni*
Smallmouth buffalo	*Ictiobus bubalus*
Bigmouth buffalo	*Ictiobus cyprinellus*
Black bullhead	*Ictalurus melas*
Yellow bullhead	*Ictalurus natalis*
Brown bullhead	*Ictalurus nebulosus*
Channel catfish	*Ictalurus punctatus*
White bass	*Morone chrysops*
Striped bass	*Morone saxatilis*
Green sunfish	*Lepomis cyanellus*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*Micropterus salmoides*
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*
Yellow perch	*Perca flavescens*
Sauger	*Stizostedion canadense*
Walleye	*Stizostedion vitreum vitreum*
Freshwater drum	*Aplodinotus grunniens*
Mosquitofish	*Gambusia affinis*
Golden shiner	*Notemigonus crysoleucas*
Redear sunfish	*Lepomis microlophus*
Flathead catfish	*Pylodictis olivaris*
Shovelnose sturgeon	*Scaphirhynchus platorynchus*
Lake herring	*Coregonus artedii*
Emerald shiner	*Notropis atherinoides*

IV. Depth at which temperature measurements were made for lakes and reservoirs

V. Temperature data where good fish population data were available

VI. Species present

  A. Relative abundance

    1. Fish caught per man hour (creel census)
    2. Weir counts per unit of time (inclusive dates)
    3. Counts made by stream and lake surveys (expressed as the number of fish per distance of stream or number of fish per unit area) or
    4. Other

  B. Condition (i.e., healthy, diseased, stunted)

VII. Fish populations

  A. Natural reproduction
  B. Stocked with no reproduction
  C. Stocked with reproduction
  D. Transient residents

    1. Duration of residence (inclusive dates)
    2. Spawning in area

  E. Permanent residents

VIII. Observed spawning including dates and relative success

IX. Qualifying remarks:

  A. Nonstratified body of water (i.e., homothermous stream)
  B. Stratified body of water (i.e., lake or reservoir)
  C. Water with a horizontal gradient (i.e., thermal discharges)
  D. If temperature measurements were from a:

    1. Low gradient river, then areas up and/or downstream were used in reaches not influenced by thermal discharges and in reaches considered to have the same temperatures.
    2. Small impoundment used only for diversion, then species were included in the stream category.
    3. High gradient stream at the mouth of a canyon, only species present above were included and for a distance not exceeding a rise in elevation of 500 feet.

Data in the above categories were analyzed, and after analysis, edited for applicability in the study. The surviving categories and organization of the encoding formats was then formalized into computer data card-sized records. A general description of the six data encoding formats comprising the 80-character input records utilized in the FTDMS is as follows:

Data Sheet	General Description
I (one sheet per station)	Data included in this category describes the data location (latitude and longitude coordinates) and other geophysical characteristics.
J (maximum of nine (9) sheets per station)	This category includes the code numbers relating to the various bibliographic entries (accession numbers) and special events (dam construction, river channelization, etc.) peculiar to the station defined by the "I" data sheet.
K (one sheet per station)	This entry allows a total of 80 characters for the station common name ("Mississippi River Pool 1", etc.).
T (no sheet limit)	All water temperature information for a particular station location is encoded on these sheets.
F (no sheet limit)	All fish sampling information for a particular station is encoded on these sheets.
B (no sheet limit)	Fish spawning or other biological data are encoded on these sheets.

A detailed description of the input categories for each of these formats is included as Appendix B. (The reader should refer to these for decoding printouts in this section.)

All of the sheets comprising a station set were interrelated by a station code number which was affixed by the encoder at the time the data were transcribed. This number is a six-digit integer of which the first two digits indicate the state code. The last four-digits identify the station in the sequence of accession (see Appendix C).

During the course of the study, three major changes were made in the format of these sheets which will be discussed here. These changes were the result of experience and use of the study data base and computer programs; it is expected that future users will have requirements which will necessitate still other system modifications.

The first major change in the encoding format affected the J-data sheet, particularly, in terms of the inclusion of bibliographic accession numbers and special event codes. The accession numbers are in the range of 000,001 through 899,999 and are assigned to all documents containing fish-temperature data or ancillary information used.

The special event codes are in the range 900,000 through 999,999 and are used to reference physical or functional changes in the station environment which could affect the use or interpretation of the encoded data. Examples of these special events are such occurrences as the construction dates for a local dam, major flood dates and resulting stream changes, and man-made changes such as channelization and dredging. Additionally, biological information reported for a particular fish species or fish population, such as characteristic spawning behavior in a geographic region that may be different from other regions, is referenced via these codes.

The format of the temperature encoding data sheet was also changed to allow for a more compact transcription of data. Basically, the present format provides a data sheet for recording daily temperature values and a second format for the weekly, monthly, quarterly, and annual data. One other change on this sheet allows an identifying code number for the type of temperature sensing equipment used in the field sampling. This provides data from which a subjective evaluation of the quality of the temperature data can be made. Additionally, it provides the basis for determining the frequency of use of particular equipment types.

The final major modification to the format of the data encoding sheets was the incorporation of alpha-numeric data descriptor codes, or alpha codes. This addition to the data base was dictated by the data variability and the subsequent need for qualifying remarks. As presently used, the code consists of a maximum of seven characters, the first two of which must be alphabetic, the last five integers. A complete listing and description of these codes is presented as Appendix D but a brief example will be given here to show their intended utility.

Using the previous example of the indefinite fish "count" statistic, assume that a data entry for a particular station was presented in terms of a fish sample rate, say, 13 rainbow trout (Salmo gairdneri) per stream-mile. The corresponding spawning temperature data collected for this date and station is given as a range, 48 F to 52 F (8.9 C to 11.1 C). The correct procedure for encoding these data consistent with the present system methodology would be as follows: (1) Estimate the length of the stream in miles controlled by the station. If this is not available in the source document, it would be necessary either to refer to a map of the subject station or obtain this information by letter or phone. For purposes of this example, suppose it is determined that the control length is 10 miles. The resultant "count" would be encoded as 130 and the corresponding alpha code would be entered as AA00013 and CF00010, signifying the source data as a catch-rate per stream-mile of 13 fish and an assumption for the stream length as 10 miles. (2) The spawning temperature data would be encoded as 48 F (8.9 C) for the observed low and a high of 52 F (11.1 C). The alpha code supporting these entries would be EG48.52, or the temperature range is 48 F to 52 F (8.9 C to 11.1 C).

The next step in the encoding process was the transformation of the encoded data into magnetic characters on a computer data tape. The data resulting from this process became the input to the computer programs which format, sort, edit, and re-store these data in a series of operations which ultimately yielded a magnetic tape called the Master Tape. The important logic steps describing this process is the subject of the subsequent text. Table 3 presents a summary of the various computer programs, or routines, discussed in the next sections. The discussion of these follow in the order of the table.

DATA STORAGE

The data storage process included transformation of the encoded data to a format compatable to high-speed, large computers. The initial study utilized a Univac 1108 computer system with an EXEC VIII controller/auditor. This system is shown schematically as Figure 2. In general, the data base Master Tapes are adaptable to other machines with very little modification; however, the computer program logic (FORTRAN IV) is presently Univac 1108 specific and would require some modifications for other processing systems.

The computer logic sorts the data by station number and record type, and within these records as follows:

I - one card only per station
J - by serial number to a maximum of nine
K - one card only per station
T - by increasing date and depth
F - by increasing date and depth
B - by increasing date and species number

The resulting magnetic data tape becomes the input to program STORE.

Computer Program STORE

This program uses as input the ordered data on the "complete station" tape made by the process described above.

In order of increasing station number, STORE puts the data onto one of two separate Master Tapes, one of which contains all river and stream data, the other all other types of water bodies, such as lakes, reservoirs, etc.

The data for each station are arranged in blocks of eleven 37-word records, as follows:

Block 1 - The identification block. This block gives general information about the station - name, location, water-body, type, elevation, etc., together with codes for source materials.

Block 2 to k - Temperature blocks. Record 1 contains the station number. Records 2-11 are 10 sets of temperatures recorded, giving year, month, whether daily, weekly, monthly data, whether maximum, minimum, or average data.

TABLE 3. FISH-TEMPERATURE COMPUTER PROGRAMS SUMMARY

Type/Name	Use
Storage	
STORE	Converts data tapes (prestored 80-column cards, binary) to master tapes (blocked, BCD)
RECOND	Converts master tapes to data tapes (for updating, editing)
ACD	General purpose editing (add, change or delete) for data tapes
DEDUP	Deletes duplicate records from data tapes
TPEDIT	General purpose editing for master tapes
Retrieval	
REGURC	Selective (by station numbers) retrieval of data from master tapes
SUMDAT	Prints contents of data tapes-MONTMP (from STUDY1), WKTMP (from STWKLY), FSHCNT (from STWKLY)
CATALOG	Provides inventory of all data on master tapes, produces data tape, FTK2
CATSRCH	Extracts selected stations' data from FTK2, any combination of parameters
STWKLY	Produces WKTMP (weekly temperatures) and FSCNT (fish counts) data tapes from master tapes
Analyses	
ALLPOSS	Determines frequency of occurrence of certain types and classes of data on the master tapes
MATRXI/OUT1	Determines fish-temperature data sets by major and minor river basins
MATRX2/OUT2	Determines fish-temperature data sets by thermal characteristic and sampling method
MATRX3/OUT3/OUTSP	Determines fish-temperature data sets by temperature and fish-catch equipment type
CFT	Compiles selected fish species data from FSHCNT-tape (from STWKLY)
FTT	Compiles matched fish-temperature records from CFT and WKTMP (from STWKLY)
WKTTAB	Uses FTT-tape to produce table of minimum, maximum and mean temperatures and corresponding fish counts
WKTPLT	Plots tabular data from WKTTAB
WKPCT1	Uses FTT-tape to produce cumulative percentiles of weekly temperatures for all species
WKPCT2	Uses WPCT1-tape to generate tables of selected percentiles, species and weeks
STUDY1	Produces fish-temperature statistics from master tape for each station and year of record
Graphics	
MPLOT	Collects data for selected station/years from STWKLY and STUDY1-tapes for plotting
ECOPLOT	Produces six types of labelled and annotated graphs from MPLOT tape

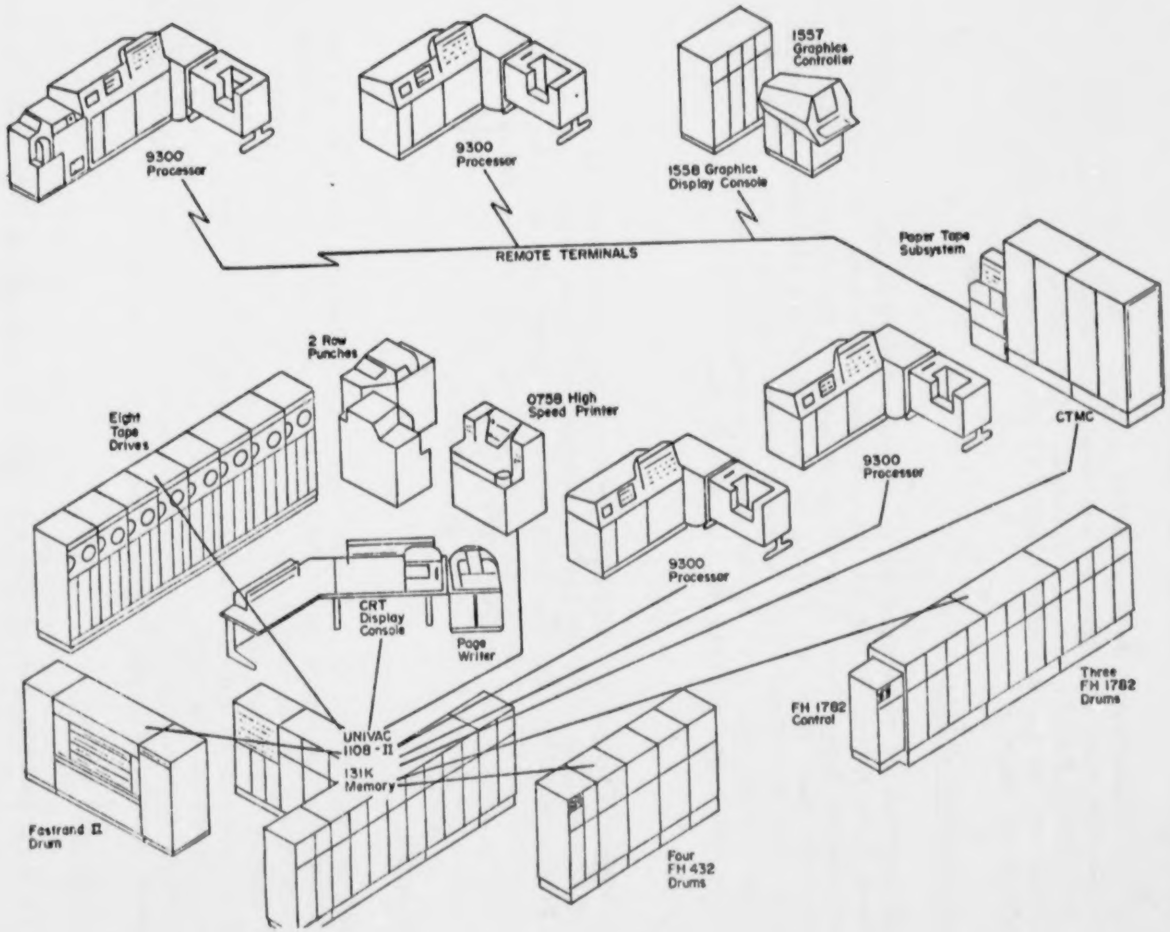
9300 Processor
9300 Processor
1557 Graphics Controller
1558 Graphics Display Console
REMOTE TERMINALS
Paper Tape Subsystem
2 Row Punches
0758 High Speed Printer
Eight Tape Drives
9300 Processor
CTMC
9300 Processor
CRT Display Console
Page Writer
UNIVAC 1108 - II
131K Memory
Fastrand II Drum
Four FH 432 Drums
FH 1782 Control
Three FH 1782 Drums

Figure 2. Schematic diagram of Univac 1108 Computer System used for fish-temperature data processing.

Blocks k+1 to ℓ - Fish blocks. Record 1 contains the station number. Records 2-11 are 10 sets of species data (number caught, method of catch, etc.).

Blocks ℓ+1 to m - Biological blocks. Record 1 contains the station number. Records 2-11 are 10 sets of general background information about the living and spawning habits of each species recorded.

Table 4 illustrates typical STORE output. New fish and temperature blocks are defined for each new year encountered, but only full blocks are printed. Also, biological blocks are not printed. This means that for station 400900 in the example, there are many blocks of incomplete (non-full) fish, temperature and biological data.

Computer Program RECOND

The purpose of this program is to make possible the reconstruction of data tapes from Master Tapes of the original data base, or conversely, to make new Master Tapes from updated data tapes. The logic of this program transfers the data from one format to the other and provides a complete listing of the 80-column card images representing the data. This program may be used either for loss or damage to a data tape, or to update a data tape after extensive editing to the Master Tape.

Editing

Adding, changing, or deleting data on the data tapes, is accomplished by the computer program ACD; duplicate records on these tapes can be eliminated by the program DEDUP. Changes to the Master Tapes can be effected by the TPEDIT routine. After this program is used on the Master Tapes and at the user's convenience, the program RECOND can be utilized to update the fish-temperature data tapes as discussed earlier.

DATA RETRIEVAL

User inspection of the encoded data on the Master Tapes is accomplished with the computer programs described in this section. There are three general types of programs in the retrieval category. The first type (REGURG and SUMDAT) simply reproduce the data corresponding to a selected station, or set of station records in the data base. The second type (CATALOG and CATSRCH) provide an index to the data compiled on each Master Tape, and the final type (STWKLY) accumulate fish population data and (weekly) temperature data for cursory examination and further analytical studies.

Computer Program REGURG

This program will output the contents of any Master Tape made by program STORE.

Selective options are available, as follows:

(1) Print all data for a given list of stations

TABLE 4. EXAMPLE OF OUTPUT FROM COMPUTER PROGRAM STORE WHICH CONVERTS DATA TAPES TO MASTER TAPES

```
Statn                    Body  Therm  Major  Minor   Lat.   Long.  Prec.  Av. iso  Evel.  Nearst Name
 No.    Record  County   type  char.  basin  basin  D/M/S  D/M/S  code    code    (ft)   code-locatn
400700    1       39      2      2     13      9    4407001222800  5        3      500    2 Vida, Oregon

                        Accession numbers
Station  400900               721921
Station  400900         McKenzie River, Oregon


                                        Station 400900     T     Temperature data
Year   Mon  Depth
                                                                                                   Tempid  Type  Samp. Eqpt
 56          0   Monthly temps   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1  370   -1      3       1       10
 56          0   Monthly temps   -1   -1   -1   -1   -1   -1   -1   -1   -1  440   -1   -1      3       1       10
 56          0   Monthly temps   -1   -1   -1   -1   -1   -1   -1   -1   -1  520   -1   -1      3       2       10
 56          0   Monthly temps   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1  480   -1      3       2       10
 56          0   Monthly temps   -1   -1   -1   -1   -1   -1   -1   -1  560   -1   -1   -1      3       2       10
 56          0   Monthly temps   -1   -1   -1   -1   -1   -1  600   -1   -1   -1   -1   -1      3       2       10
 56          0   Monthly temps   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1   -1  470      3       2       10
 56          0   Monthly temps   -1   -1   -1   -1   -1   -1   -1  590   -1   -1   -1   -1      3       2       10
 56          0   Monthly temps   -1   -1   -1   -1   -1  540   -1   -1   -1   -1   -1   -1      3       2       10
 56          0   Monthly temps   -1   -1   -1   -1  490   -1   -1   -1   -1   -1   -1   -1      3       2       10

                                        Station 400900     F     Fish data
Year   Mon   Species   Day   Dep    100 Count   Method   Cond   Devel
 50     13     13       0    -1       8500        8        3      3
 -1     -1     -1      -1    -1         -1       -1       -1     -1
 -1     -1     -1      -1    -1         -1       -1       -1     -1
 -1     -1     -1      -1    -1         -1       -1       -1     -1
 -1     -1     -1      -1    -1         -1       -1       -1     -1
 -1     -1     -1      -1    -1         -1       -1       -1     -1
 -1     -1     -1      -1    -1         -1       -1       -1     -1
 -1     -1     -1      -1    -1         -1       -1       -1     -1
 -1     -1     -1      -1    -1         -1       -1       -1     -1
 -1     -1     -1      -1    -1         -1       -1       -1     -1
```

(2) Print the ID-block
(3) Print the T-blocks
(4) Print the F-blocks
(5) Print the B-blocks
(6) Print the I-records (first record of ID block) geographical data
OR Print the J-records (non-blank records 2 through 10 of ID-block) accession numbers
OR Print the K-records (last record of ID-block) complete station name.

An example of the output of this routine is shown in Table 5 and is described as follows:

The data block headed "Contents of I Record" contains the information supplied by the "I Card" data sheet. The pertinent numbers relating to the two lines of descriptors starting with "Station" and "State", respectively, are contained in the two rows directly below (rows 3 and 4). For example, in Table 5 the station number is 50300, the latitude is 41°55'00"N, the longitude is 122°26"00"W, the precision of this position is within one minute (code 5) and the station is located in a 52 F (11.1 C) isotherm area. Similarly, for the next row (row 4) the state is California (CA) in Siskiyou County (county 93) the nearest landmark is Hornbrook (a town) (code 2) the major river basin is California (code 14) the minor river basin is Klamath River (code 1) and the type of water body is classified as a river (code 2) and the name of the river is Klamath River.

The contents of the J-record, which follow, is typical of the type of information included to identify sources of information and other related comments. The contents of this record are bibliographic and reference code or accession numbers which relate to pertinent documents or comments which describe the encoded data or station operation. The K-record contains the station name and location identifier which provide a geographical locus for each station and can be used as a label for various table and graphic outputs.

The "temperature data" information include an identification record which contains the station number and the letter "T" (signifying temperature). The remaining information in this record is comprised of temperature data for all the dates (year and month) of record and for all sampling depths. The values of minus one (-1) in the temperature matrix, indicate "no value given". For example, from the table included for the data of March 1963 at surface depth (zero) on the fifteenth day, there is registered a 43 F (6.1 C) temperature. The temperature type (T-ID) and class (T-CLASS) given at the right-hand side of this record indicates that the temperature given is DAILY-MINIMUM (codes 3 and 1).

The "fish-data" also begins with an identification record containing the station number. Succeeding rows of data contain all of the input to the computer on the F-cards. From left-to-right in order of appearance, these values are:

TABLE 5. EXAMPLE OF OUTPUT FROM COMPUTER PROGRAM REGURG WHICH SELECTIVELY RETRIEVES DATA FROM MASTER TAPES

```
Contents of I Records

Station  ID   Latitude  Longitude   Prec  150
State  Cnty  Nr  Identification       Maj Min Type Body Name                    Thermal

 50300   1      415500   1222600      5  520
Ca      93  2Hornbrook                 14   1   2Klamath River                    2
--------------------------------------------------------------------------------------
Contents of J records

Riley, James O., Jr., Region 1, Inland Fisheries, Annual Report, Iron Gate

Salmon - Steelhead Hatchery Operations 1965-1968, California Department

Fish and Game, Administrative Reports 67-8, 67-15, 68-10

Marshall, Laird C., Annual Report Iron Gate Salmon - Steelhead Hatchery

1969-70, Calif. Department of Fish-Game, Administrative Report Number 70-17
--------------------------------------------------------------------------------------
Content of K Record

Station Name          F or T  Precision Sta. Type  Elev  Av.150  Str. Grad.  Qlty State Folor

Iron Gate Hatchery        3       5         3     -10000  520       -1        Oca    03A
--------------------------------------------------------------------------------------
Contents of temperature buffer

Station  ID   Latitude  Longitude   Prec  150

 50000   T     415500   1223600       5   520

Year  Month  Depth                Temps for day
  1     2      3     4     5     6     7     8     9    10    11    12    13    14    15    16
 17    18     19    20    21    22    23    24    25    26    27    28    29    30    31    T-ID TClass

 63     3      0
430   430    421   421   421   421   430   430   430   441   441   441   430   430   430   421
430   421    430   430   410   421   421   421   430   430   430   430   430   430   430        3    1

 63     3      0
441   430    430   430   421   430   441   441   441   441   441   441   441   441   430   430
430   430    441   441   441   421   421   441   441   441   430   441   441   441   441        3    2
CONTINUES FOR MONTHS AND YEARS
--------------------------------------------------------------------------------------

Contents of Fish Buffer

Station   ID  Latitude  Longitude  Prec 150

 50000    F      415500  1222600    5   520

 Yr  Mon  Sp  Sf   Dp   Count·100  U/A  KP  PP  CN  NTV  ST  TR  Res-MO.  SP  SP-MO.   SUC   QLF  IMP
 65   7   10  24   -1      100      5    6   3   4   1   10   1   -1  -1   10  -1  -1   10     10   1
 65   9   46  24   -1      100      5    6   3   4   1   10   1   -1  -1   10  -1  -1   10     10   1
 65   9   10  27   -1      200      5    6   3   4   1   10   1   -1  -1   10  -1  -1   10     10   1
 65   9   10  29   -1      200      5    6   3   4   1   10   1   -1  -1   10  -1  -1   10     10   1
 65   9   46  29   -1      200      5    6   3   4   1   10   1   -1  -1   10  -1  -1   10     10   1
 65   9   10  30   -1     1400      5    6   3   4   1   10   1   -1  -1   10  -1  -1   10     10   1
 65   9   46  30   -1      400      5    6   3   4   1   10   1   -1  -1   10  -1  -1   10     10   1
 65  10   46   3   -1      300      5    6   3   4   1   10   1   -1  -1   10  -1  -1   10     10   1
 65  10   10   4   -1     1300      5    6   3   4   1   10   1   -1  -1   10  -1  -1   10     10   1
 65  10   46   4   -1      200      5    6   3   4   1   10   1   -1  -1   10  -1  -1   10     10   1
CONTENTS OF FISH BUFFER CONTINUES
```

YR = Sampling year
MO = Sampling month
SP = Species number
SF = Day of month
DP = Sampling depth
COUNT*100 = Sample size multiplied by 100
U/A = Count units, e.g., 5 = per day
KP = Capture method, e.g., 4 = creel census
PP = Population quantifier, e.g., 1 = abundant
CN = Condition of the species in the sample, e.g., 4 = not given
NTV = Native species code, e.g., 1 = yes, 2 = no
ST = Stocked species code, e.g., 1 = stocked with no reproduction
TR = Transient species code, e.g., 1 = transient
RES-MO. = Duration (in months) species is resident, i.e., beginning and ending
SP = Spawning code, e.g., 1 = transient spawning occurs
SP-MO. = Duration (in months) spawning was observed, i.e., beginning and ending
SUC = Degree of spawning success, e.g., 1 = good
QLF = Water quality code, e.g., 1 = thermal discharge
IMP = Species importance code, e.g., 1 = most important

For any of the data noted as having a value of ten (10) or minus one (-1), the entries in these categories were not available or not given. At the conclusion of each station data block, a summary of record statements is included to indicate the total number of records for all data and the number of data cards input to each record block. (i.e., A record block is defined in computer storage as that space necessary to contain 396 words, or data values.)

Computer Program SUMDAT

This program is set up to print the contents of each of the three summary data tapes:

MONTMP - monthly minimum, maximum, and mean temperatures at each station for each year of record (from STUDY1)
WKTMP - weekly minimum, mean, and maximum temperatures at each station for each year of record (from STWKLY)
FSHCNT - total fish count and count for all species at each station for each year of record (from STWKLY).

As may be seen in Table 6, the output of this routine is simply a formatted tape dump, useful primarily in pinpointing bad records when they create difficulties during processing by the analytical routines. The example is a dump of a fish-tape: 250100 is the station number, 49 is the year, and 1048 is the total number of fish of all species caught at that station during that year. The numbers that follow are fish counts for individual species, the species number being represented by its position. For example, in 1949 at station 250100, species one through twelve were not found. Fifty-seven individuals of species thirteen were recorded, none of species fourteen, and 198 of species fifteen. (See Appendix A for names of fish corresponding to species number.)

TABLE 6. EXAMPLE OF OUTPUT FROM COMPUTER PROGRAM SUMDAT

```
                                                                                           Date  030372    Page 7
          Reading Tape FSHTOT No. 11     Record Length 503
             250100         49      1048

   1     0     0     0     0     0     0     0     0     0     0     0     0     57     0     198     793     0     0
  19     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
  37     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
  55     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
  73     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
  91     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
 108     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
 127     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
 145     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
 163     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
 181     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
             250100         50      1190

   1     0     0     0     0     0     0     0     0     0     0     0     0     19     0     255     917     0     0
  19     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
  37     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
  55     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
  73     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
  91     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
 108     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
 127     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
 145     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
 163     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0     0
 181     0     0     0     0     0     0     0     0     0     0     0     0      0     0       0       0     0
             250100         91       691
Table continues - but not included
```

Computer Program CATALOG

This program provides an inventory on tape of basic data regarding all stations on the Master Tapes.

Using the Master Tapes as input, CATALOG abstracts from them the following data, which are put on a separate tape FTK2 for ready reference:

- Record length
- Station number
- ID of Master Tape where the station is stored
- 2-letter state code
- Water body type
- Major basin
- Minor basin
- Latitude
- Longitude
- Isotherm range
- EPA region
- A list of all species present

CATALOG may be used to produce a concise table of contents for a Master Tape (Table 7). As a rough yardstick, the entire data base consists of ten Master Tapes (or 24,000 feet of tape). Column 1 headed "length", indicates the number of blocks of data in the record. The blocks contain 407 computer words each. The remaining columns contain areal descriptors except "tape", which simply identifies the Master Tape being read. Species found at a station are indicated by the species code in the second line. For example, in Table 7, station 20500 has catch records for species, 8, 9, 10, 13, 72, 96 and 199.

CATALOG's primary value, however, lies in the production of the catalog tape, the use of which is outlined in the following description of program CATSRCH.

Computer Program CATSRCH

This program can be used to search the tape made by program CATALOG, tape FTK2, for specific information. One or more of the classes of data may be retrieved in one pass. For example, if one desired to know which stations in a given major basin, between given latitudes and longitudes, contained eight particular species, CATSRCH reads FTK2 and prints out all the stations meeting any of these specifications.

In one study it was necessary to know at what stations any or all of a list of 50 species occurred. The numeric code for each species was input to CATSRCH and output from the program is as shown in Table 8. Notice that the only difference between the output of CATALOG and CATSRCH in this case, other than the transposition of some columns, is the deletion of records not associated with species in the input list. For example, species 8, 10, 72, 96 and 196 were not requested in the input deck so no longer show up at station 20500, as they did in the CATALOG output.

TABLE 7. EXAMPLE OF OUTPUT FROM COMPUTER PROGRAM <u>CATALOG</u> WHICH PROVIDES INVENTORY OF ALL DATA ON MASTER TAPES FOR EACH STATION

```
                                                                                (Followed by species list)
Length  Station   Tape    State  Body type    Lat      Long   Min Iso  Max Iso  Maj Bsn  Min Bsn  EPA Region

  12     10200   546051   Al         2          0        0       5        8        0        0          4
                            41
  15     20100   546051   AK          3    562300  1343800    32       39       16       12         10
                            6   7   8   10
  13     20300   546051   AK          3    562700  1324200    32       39       16       12         10
                            6   7
  18     20500   546051   AK          3    613600  1490600     5        8        0        0         10
                            8   9  10   13   72   96  199
  19     20700   546051   AK          3    572404  1350502    32       39       16       12         10
                            6   7   8    9   12   13   46   92
  16     20800   546051   AK          3    572100  1342400    32       39       16       12         10
                            6   7   8   92  209
  21     20900   546051   AK          3    595400  1495100    32       39       16        8         10
                            6   7   8   10   13   46   64   92   96
  18     21000   546051   AK          3    611300  1493800    32       39       16        8         10
                            6   7   8   10   13   92  225
  15     21100   546051   AK          3    611000  1494600    32       39       16        8         10
                            8   9  10   92
  12     21200   546051   AK          3    620000  1460000    32       39       16       10         10
                          105
  19     21500   546051   AK          2    600700  1492400    32       39       16        8         10
                            6   8   9   10   13   92  105  196
  12     21800   546051   AK          2    592000  1555000    32       39       16        5         10
                            9
  18     21900   546051   AK          3    611200  1494000    32       39       16        8         10
                            8   9  10   13   45   92  105
```

TABLE 8. EXAMPLE OF OUTPUT FROM COMPUTER PROGRAM CATSRCH WHICH EXTRACTS SELECTED STATION DATA

```
Variable   Value(s)  Station No.  Tape Number  State  Body Type  Latitude  Longitude  Min/Max  Major Basin  Minor Basin  EPA Reg

                      561600                    WI        1       430600    892600    40  44       7            9           5
Species       40     42     114
                      561700                    WI        1       480200    894100    40  44       7            7           5
Species       17
                      561800                    WI        1            0         0     5   8       0            0           5
Species       25
                      561900                    WI        1            0         0     5   8       0            0           5
Species       17
                      570000                    WY        1            0         0     5   8       0            0           8
Species       11
                      570300                    WY        1       431200   1083600    45  49       9            1           8
Species       22     25   35   37   39   40   42
                      570600                    WY        1            0         0     5   8       0            0           8
Species       24
                      10200      546051         AL        2            0         0     5   8       0            0           4
Species       41
                      20100      546051         AK        3       562300   1343800    32  39      16           12          10
Species        6     7   8   10
                      20200      546051         AK        3       562700   1324200    32  39      16           12          10
Species        6     7
                      20300      546051         AK        3       562700   1324200    32  39      16           12          10
Species        6     7
                      20400      546051         AK        3       562700   1324200    32  39      16           12          10
Species        6     7
                      20400      546051         AK        3       613600   1490600     5   8       0            0          10
Species        8     9   10   13
                      20500      546051         AK        3       613600   1490600     5   8       0            0          10
Species        8     9   13
```

Computer Program STWKLY

This program is used to accumulate two kinds of data from a Master Tape:

(1) Weekly minimum, maximum, and average temperature at each station for each year of record.
(2) Total fish count of each species for each station per year.

All data are printed for each year of record. In addition, the data are written on one of two tapes, TEMPWK having the weekly temperature data and FSHCNT having the weekly total fish count by species.

An example of STWKLY temperature output is shown in Table 9. Temperatures are ordered across the page by week so that station 20100, week 1, 1935 has an average minimum temperature of 31.3 F (-0.67 C), average maximum of 31.4 F (-0.67 C) and average mean of 31.4 F (-0.67 C). Week 27, 1935 has an average minimum of 48.4 F (8.91 C), average maximum of 51.9 F (11.1 C) and average mean of 50.1 F (10.0 C). STWKLY fish output starts in the lower section of Table 9. During the year 1935 at station 20100, 6,040 individuals of species 6 were counted.

STWKLY is most useful in the production of the fish count and weekly temperature tapes, which become input for many of the analytical programs.

DATA ANALYSES

Currently, the FTDMS provides the user a fairly wide range of data summary presentations with which to support further analyses or detailed examinations of the data base. The philosophy behind these presentations is to allow human inspection and intervention rather than to impose on the computer logical decisions which are premature or result in superficial or erroneous conclusions. Since the data base accumulated to date is large and is expected to get much larger, the purpose of the analytical routines developed thus far is to allow the user the facility to answer the following questions: (1) How much data resides in the data base in specific categories of interest? (2) What is the summary content of these data for specific geographical locations or species?, and (3) What conclusions can be drawn from basic statistical presentations of selected data combinations? Currently, there are over twelve routines which form the analytical capability of the FTDMS. The purpose of each and a brief example of each output table will be given in the subsequent text.

Computer Program ALLPOSS

This program does a scan of Master Tapes to provide a quick summary of information to aid in making decisions as to what kinds of statistical studies could be made for a given set of stations.

Four categories of data may be requested from input of up to four Master Tapes for any one run of this program. Each category of data is accumulated from all the input tapes and printed out before data for the next category are compiled. The four kinds of data are accumulated by the following subroutines:

TABLE 9. EXAMPLE OF OUTPUT FROM COMPUTER PROGRAM STWKLY WHICH PRODUCES WEEKLY TEMPERATURES AND FISH COUNTS DATA FROM MASTER TAPES

```
Station 20100    Sashin Creek on Little Port Walter Bay, Baranof Island, Alaska              Year 35
 31.3 30.9 30.6 31.4 33.9 34.3 33.6 33.6 32.4 31.0 31.6 31.6 30.9 31.4 32.9 33.3 33.6 34.6 35.3 36.4 37.1 39.1 42.1 43.7 46.9 45.7
 48.4 50.6 51.6 53.3 54.3 52.7 51.7 52.0 52.7 51.3 49.7 47.3 46.9 48.7 43.6 41.9 39.0 34.9 36.3 33.6 35.7 30.9 36.0 35.9 37.7 36.4
 31.4 31.3 39.9 31.7 34.4 37.6 34.4 34.4 33.6 31.4 33.1 32.4 33.6 36.3 36.0 35.1 36.9 37.3 38.6 38.7 40.7 41.9 45.7 46.1 50.1 47.4
 51.9 52.7 55.1 59.6 69.4 55.3 56.3 54.3 57.0 54.9 63.6 49.9 49.0 49.9 46.1 43.4 41.0 36.9 39.0 34.9 37.1 40.3 37.6 37.1 38.9 37.3
 31.4 31.3 39.7 31.6 34.1 34.3 34.9 34.0 33.3 31.2 32.4 32.0 32.2 33.9 34.3 34.2 35.2 35.9 36.9 37.6 38.9 40.5 43.9 44.9 48.5 46.6
 50.1 51.6 53.4 56.4 56.9 54.0 54.0 53.1 54.9 54.1 51.6 48.6 47.9 49.3 44.9 42.6 40.0 35.9 37.6 34.2 36.4 39.6 36.8 36.5 38.3 36.9

Station 20100    Sashin Creek on Little Port Walter Bay, Barnaof Island, Alaska              Year 36
 35.3 33.4 31.7 32.6 31.3 31.0 31.0 30.9 32.0 33.1 32.6 31.3 31.0 31.9 33.6 34.3 34.9 36.1 36.7 39.4 40.4 45.9 51.1 54.1 54.3 55.6
 56.7 55.9 56.6 57.0 57.1 53.6 54.6 54.3 54.0 52.3 46.0 40.6 47.0 47.3 47.6 45.4 46.1 42.6 42.4 44.3 43.0 42.0 36.0 35.9 34.4 31.6
 35.4 34.4 32.7 33.4 32.6 31.0 31.0 31.1 32.6 34.4 34.4 33.4 32.4 34.1 35.1 36.7 39.6 39.6 40.9 42.4 43.6 52.9 59.4 60.7 61.1 63.3
 61.9 58.6 61.4 62.7 63.3 54.4 59.1 59.9 59.1 54.7 49.1 49.9 48.7 48.9 49.0 47.7 47.7 43.7 44.0 45.3 44.3 44.4 38.1 36.1 35.6 33.9
 34.9 33.9 32.3 33.0 31.9 31.0 31.0 31.0 32.3 33.8 33.5 32.4 33.7 33.0 34.4 35.5 37.2 37.9 38.8 40.9 42.0 49.4 55.3 57.4 57.7 59.4
 59.3 56.7 59.0 59.9 60.2 54.0 56.9 57.1 56.6 58.5 47.6 49.2 47.9 48.1 48.3 46.6 46.9 43.1 43.2 44.0 43.6 43.5 37.1 37.0 35.0 32.7
    CONTINUES FOR OTHER YEARS AND STATIONS

   Sashin Creek on Little Port Walter Bay, Baranof Island, Alaska            Station  20100  Year 35  Total Count  6040
   SPC    Count SPC   Count SPC   Count SPC   Count SPC   Count SPC   Count SPC   Count SPC   Count SPC   Count SPC   Count
    6      6040
   Sashin Creek on Little Port Walter Bay, Baranof Island, Alaska            Station  20100  Year 36  Total Count  5240
   SPC    Count SPC   Count SPC   Count SPC   Count SPC   Count SPC   Count SPC   Count SPC   Count SPC   Count SPC   Count
    6      5164  7      26  8      40
Table continues - but not included.
```

(a) POSSA1 - Occurrence of each species. The fish blocks for each station are searched for all species and all methods of capture. If no fish blocks are found, a diagnostic is printed. Otherwise, at the end of fish data for each station, the program prints for each species the number of occurrences of each capture method, followed by the years in which these data were collected. Output from POSSA1 is shown in Table 10. The relative effectiveness of various types of capture techniques on a particular fish species in a particular location is amply demonstrated. For example, in Table 10, while rainbow trout (#13) catch is poor by seine and better with electric shock, the reverse is true for fathead minnow (Pimephales promelas) (#23).

(b) POSSA2 - Correlation of species presence with water temperature. The temperature blocks for each station are searched for daily surface data. Maximum and minimum temperatures only are collected. If there are no temperatures for a given station, no further data collection is made, and the program increments to the next station. Also, if there are temperature statistics accumulated, but no fish data are available, the program increments to the next station. Given that both temperature and fish data exist for a station, the averages of the maximum and minimum temperatures for each month are printed, followed by a list of the number of occurrences of each species in that month (Table 11). The years of record from which this information was derived are also printed.

(c) POSSA3 - Accumulator of categories of temperature data and species present for each station. This sub-routine searches the Master Tapes for each station's temperature records and adds the number of occurrences in each category of temperature data (daily, weekly, monthly, etc.). It then accumulates a list of the species present at each station. Printouts consist of the number of times a particular category of temperature data appear, followed by a list of the years for which species data were found. POSSA3 would be most valuable in the feasibility study stage of any fish-temperature analysis. In Table 12, for all the stations listed there exists daily temperature data, but for none of them is there continuous, seasonal, weekly, quarterly, or annual data (these categories could, of course, be constructed given ample daily data).

(d) POSSA4 - Spawning data. A search of the B-blocks on the input Master Tapes is made in search of spawning data. If some information is found, the species is noted. At the end of searching each station, the printout consists of either a notation that for that station no spawning information was found or a list of the species for which such information was available. POSSA4 provides the type of information necessary to pinpoint optimum spawning conditions. Table 13 is representative of the sparsity of data related to this phenomenon. Two items in the output requiring elucidation are that the B adjacent the species column is a program check that indicates Biographic Data, and the SUCC column gives spawning success where 1 = good, 2 = poor, 3 = not given.

MATRIX Programs

The seven matrix programs (MATRX1, MATRX2, MATRX3, OUT1, OUT2, OUT3, and OUTSP) will be discussed together.

TABLE 10. EXAMPLE OF OUTPUT FROM COMPUTER PROGRAM <u>POSSA1</u> (SEE TEXT)

```
            Composite Possa Program Aug 26, 1971   CJ            Date 082671    Page 20

                               Station 490100        Tape No. FT5001

                                    Capture Method for species shown
      Species            Elctro  Gilnet   Weir   Creel   Poison   Ladder   Seine   Trap   Stroiv
 ------------------------------------------------------------------------------------------------
  2  Alewife                0       0       0      0       0        0        1       0      0
 11  Mnin Whtfish           0       0       0      0       0        0        2       0      0
 13  Rainbw Trout          15       3       0      0       0        0        2       0      0
 22  Carp                  16       1       0      0       0        0       14       0      0
 23  Fahd Minnow            3       2       0      0       0        0       39       0      0
 25  White Sucker           2       1       0      0       0        0        4       0      0
 28  Black Bulhed           1       0       0      0       0        0        1       0      0
 31  Chnel Catfsh           4       6       0      0       0        0        1       0      0
 47  Colrdo Chub            5      15       0      0       0        0       24       0      0
 49  Colrdo Sqfsh           2       4       0      0       0        0        1       0      0
 50  Spkled Dace            2       1       0      0       0        0       36       0      0
 51  Flnlmth Sckr          20      25       0      0       0        0       27       0      0
 52  Bluhd Sucker          20       5       0      0       0        0       20       0      0
 53  Hmpok Sucker           2       1       0      0       0        0        0       0      0
 54  Mottld Sclfn           0       1       0      0       0        0        2       0      0
 55  Utah Chub              0       0       0      0       0        0        1       0      0
 56  Redsid Shinr          10       8       0      0       0        0       41       0      0
 57  Creek Chub             0       0       0      0       0        0        2       0      0
 85  Plns Mt Scxr           0       6       0      0       0        0        3       0      0
              Years of Record 59   64      65     66
 ------------------------------------------------------------------------------------------------
```

Note - Values shown are number of occurrences.

TABLE 11. EXAMPLE OF OUTPUT FROM COMPUTER PROGRAM POSSA2 (SEE TEXT)

```
        Composite POSSA Program Aug 26, 1971    CJ                      Date 082671          Page  44

                                           Station 50200        Tape No. FTS001

    Frequency of occurrence of given species within MIN/MAX temperature band, by month and population class

                  Jan    Feb    Mar    Apr    May    Jun    Jul    Aug    Sep    Oct    Nov    Dec     Annual
Av•Min•Temp      38.4   41.3   41.7   44.7   45.8   50.2   55.2   54.7   53.6   47.7   41.6   40.0     -1.0
Av•Max•Temp      43.8   45.7   49.1   51.0   55.9   61.1   66.1   64.0   62.5   50.8   50.6   45.4     -1.0

Species Pop
        Type

  10    Abund       0      0      0      0      0      0      0      0     19     84     15      0        0
  10    Common      0      0      0      0      0     17     21     10     54    104     57      3        0
  10    Scarce      0      0      0      0      1      6      6      1      3      1     40      9        0

  46    Abund       1      5     18      1      0      0      0      0      0      2      9      4        0
  46    Common      7     39     63     44      1      0      0      0      2     24     34      7        0
  46    Scarce      5     22     26     20     18     20     23      4     46    111     40     13        0

   8    Common      0      0      0      0      0      0      0      0      0      2     28      8        0
   8    Scarce      5      1      1      0      0      0      0      0      1     49     71     20        0

  15    Abund       0      0      0      0      0      0      0      0      0      0      0      0        1
  15    Common      0      0      0      0      0      1      0      0      0      0      0      0        3
  15    Scarce      0      0      0      0      0     12      0      0      0      0      0      0        0

 Note Temp -   -1 means not given

   10   Chinook Slmn
   46   Stlhd Trout
    8   Coho Salmon
   15   Brown Trout

       Years of Record  51   52   53   54   55   57   58   59   60   61   62   63   64   65   66   67   68
```

TABLE 12. EXAMPLE OF OUTPUT FROM COMPUTER PROGRAM POSSA3 (SEE TEXT)

```
        Composite POSSA program Aug 26, 1971  CJ                              Date 082671      Page 40
  No. of occurrences of each temperature type/each station, followed by list of species    Tape No. FTS001
Station Body      Temp Type   Continuous    Seasonal    Daily    Weekly    Monthly   Quarterly  Annual  Other Period

 50200  Stream
          Temperatures            0              0        555       0         0          0          0          0
          Years of Record     51     52    53   54   55   57   50   59   60   61   62   63   64   65   66   67   68
          Species P       8  10  15  46
          Years of Record     50     59    60   61   62   63   64   65   66   67   68
 50600  Stream
          Temperatures            0              0         55       0         0          0          0          0
          Years of Record     53     54    55   56   57   58   59   60   61
          Species P      11  13  15  16    50  72  88  98
          Years of Record     53     54    55   56   57   58   59   60   61
150400  Stream
          Temperatures            0              0        259       0         0          0          0          0
          Years of Record     59     60    61   62   63   64   65   66   67   68   69
          Species P S    10  11  12  13    36  46  56  59   63  65  68  72  74  77  92  96
          Years of Record     50     51    52   53   54   55   56   57   58   59   60   61   62   63   64   65   66   67
150500  Stream
          Temperatures            0              0         92       0         0          0          0          0
          Years of Record     57     58    59   67   68   69
          Species P      11  12  13  50    56  59  63  68   72  73  77  92  94  96
          Years of Record     54     55    62   63
340100  Stream
          Temperatures            0              0        177       0        21          0          0          0
          Years of Record     54     55    56   57   58   59   60   61   62   63   64   65   66   67   68
          Species P      13  15  22  23    25  28  31  34   35  45  47  49  50  51  52  54  85  93
          Years of Record     61     63    64   65   67   68
400100  Stream
          Temperatures            0              0        164       0         0          0          0          0
          Years of Record     47     48    49   50   52   58   59   60   61   62
          Species P S     8  10  13  46
          Years of Record     42     43    44   45   46   47   48   49   50   51   52   53   54   55   56   57   58   59
                              60     61    62   64   65   66   67   68
```

TABLE 11 EXAMPLE OF OUTPUT FROM COMPUTER PROGRAM <u>POSSA4</u> (SEE TEXT)

```
               Composite POSSA Program  Nov , 1971     CJ        0020                  Date 011372     Page 41
                                                          POSSA4 Requested
                                                   Following data are from tape  LAK201
Station      Species  Year     Succ      From      To      Min. Spawng  Max. Spawng  Opt. Spawng  Peak Spawng  Peak Spawng
                                        Mo/Day   Mo/Day       Temp         Temp         Temp         Month         Day

 160100       37  B    68       1       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.
 160100       35  B    70       2       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.
 160100       37  B    70       1       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.
 160100       22  B    70       1       6   0    6   0       -1.00        -1.00        -1.00         -1.           -1.
Station      Species  Year     Succ      From      To      Min. Spawng  Max. Spawng  Opt. Spawng  Peak Spawng  Peak Spawng
                                        Mo/Day   Mo/Day       Temp         Temp         Temp         Month         Day

 160200       22  B    67       1       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.
 160200       38  B    67       1       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.
 160200       35  B    68       2       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.
 160200       37  B    68       2       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.
 160200       37  B    68       2       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.
 160200       35  B    69       1       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.
 160200       37  B    69       1       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.
 160200       39  B    69       1       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.
 160200       22  B    70       1       0   0    0   0       -1.00        -1.00        -1.00         -1.           -1.

                                                         End of job
Exit called from Loc.  014551
```

MATRX1/OUT1 is used to determine the fish-temperature data sets by major and minor river basins for each species. Program MATRX1 processes one Master Tape at a time, storing the accumulated matrix for Table 14 on tape "MATn" where n indicates the Master Tape and has the value of 1 or 2. Program OUT1 then uses the final tape MATn to print out data in Table 14.

MATRX2/OUT2 is used to determine fish-temperature data sets by thermal characteristics and sampling method. Program MATRX2 processes one Master Tape at a time and stores the accumulated matrix for Table 15 on tape "MXn" where n indicates the Master Tape and is assigned the value of 1 or 2. Program OUT2 then uses the final tape MXn to print out data in Table 15.

Program MATRX3 processes one Master Tape at a time, storing the accumulated matrix for Tables 16, 17, and 18 on punched cards and prints out Table 19 for stations on the Master Tape. After all Master Tapes have been processed ("lakes" or "streams"), program OUT3 reads the portion of the cards containing matrices for Tables 16 and 17 and prints them accordingly. Programs OUT1, OUT2, and OUT3 handle one set of tapes and cards for "streams" and another set of tapes and cards for "lakes". However, program OUTSP reads the remaining cards punched in program MATRX3 (minus those for Tables 16 and 17) and prints out Table 18 for both "lakes" and "streams" in one pass.

For each species, Table 14 gives the major and minor river basins in which it is located as determined from the data base, the station number, and the total number of fish-temperature (F/T) and spawning temperature (S/T) data sets available under the following current definition of a data set. In general, an F/T or S/T data set is defined as an occurrence of both fish and temperature data for at least one month within any year of record. Theoretically every station has the potential of twelve data sets per year, per species; however, the program logic which develops this table records only the first matching set for a given species.

As can be seen in Table 14, the number of S/T data sets is minimal in both the stream-river (S-R) and lake-reservoir (L-R) categories. This is attributable to the following:

(1) There is a lack of specific information in the data base referencing spawning habits of many of the fishes.
(2) A large portion of the spawning information in the data base is referenced via the alpha codes which are not selectable with the program logic for this table. (See Appendix D.)

In order to arrive at the total F/T or S/T data sets for an individual species, the user must refer to the separate listings of the stream-river (S-R) and lake-reservoir (L-R) categories. Also, the total number of F/T data sets in this table is equal to the total number in each category of Table 18. It should be noted, however, that this is not true for all tables since each one has a different number of possible combinations of parameters.

By mapping the occurrence of fishes within river basins from data obtained from similar printouts for each species, zones of distribution may

TABLE 14. EXAMPLE OF DATA OUTPUT FOR RAINBOW TROUT FOR MAJOR AND MINOR RIVER BASIN AND STATION CODES

Table for Stream-River Category — Date 072473 — Page 10

Rainbow trout

Major River Basin Code	Minor River Basin Code	Station Code	Total No. of F-T Data Sets	Total No. of S-T Data Sets
1	12		2	0
		320100	2	0
			2	0
2			16	0
	3		2	0
		321300	2	0
		351302	3	0
		410100	2	0
	14		2	0
		230200	2	0
	16		10	0
		330100	2	0
		330101	2	0
		330103	2	0
		330104	2	0
		330106	2	0
			0	0
	3		4	0
		201100	1	0
		201200	1	0
		201300	1	0
		201400	1	0
	6		2	0
		470401	1	0
		470403	1	0
	7		3	0
		470800	3	0
5			5	0
	20		5	0
		470500	3	0
		470502	2	0
7			5	1
	7		5	1
		580300	5	1
8			8	0
	27		1	0
		250100	1	0
	33		5	0

Table continues - but not included.

TABLE 15. EXAMPLE OF THE DATA OUTPUT FOR RAINBOW TROUT BY TEMPERATURE SAMPLING EQUIPMENT AND FISH COUNT SAMPLING METHOD

Output Table 2 for Stream-River Category Date 072373 Page 13

Rainbow Trout

Thermal Characteristic	Temperature Sampling Equipment	Fish Count Sampling Method																				
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21
		Total Number of F-T Data Sets																				
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	12	15	17	15	0	7	1	7	3	0	0	0	0	0	0	0	0	0	0	2	0
	1	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	4	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	20	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	2	12	8	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 16. FISH TEMPERATURE DATA SETS BY TEMPERATURE SAMPLING EQUIPMENT AND THERMAL CHARACTERISTICS

Table 3 Date 072473 Page 1

	Temperature Sampling Equipment										
Thermal Characteristics	0	1	2	3	4	5	6	7	8	9	Total
1	8	0	0	4	0	16	1	0	0	0	28
2	358	29	0	26	32	0	0	0	0	20	485
3	250	2	0	1	0	0	0	0	0	67	320
Totals	616	31	0	31	32	16	1	0	0	87	814

TABLE 17. FISH TEMPERATURE DATA SETS BY FISH COUNT SAMPLING METHODS USED FOR EACH THERMAL CHARACTERISTIC

Tables 4 Date 072473 Page 2

	Fish count sampling method																					
Thermal Characteristic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
1	13	4	0	8	0	0	12	0	0	0	4	0	0	0	0	0	0	0	0	0	0	41
2	81	37	93	134	33	55	21	38	9	3	4	6	0	39	0	0	5	2	2	41	2	605
3	7	3	12	49	0	73	7	6	1	2	0	0	0	190	0	0	5	0	0	0	0	355
Totals	101	44	105	191	33	128	40	44	10	5	8	8	0	229	0	0	10	2	2	41	2	1001

NOTE: See Appendix B for decoding thermal characteristics, temperature sampling equipment and fish count sampling method.

TABLE 18. EXAMPLE OF THE NUMBER OF FISH-TEMPERATURE DATA SETS IN THE DATA BASE FOR EACH FISH SPECIES

Date 070973 Page 9

	Species	No. of F-T Data Sets Lake-Reservoir	No. of F-T Data Sets Stream-River
1	White sturgeon	0	30
2	Alewife	10	9
3	Gizzard shad	92	69
4	Threadfin shad	47	28
5	Lake whitefish	0	0
6	Pink salmon	0	102
7	Chum salmon	0	94
8	Coho salmon	6	176
9	Sockeye salmon	0	104
10	Chinook salmon	10	208
11	Mountain whitefish	23	109
12	Cutthroat trout	24	43
13	Rainbow trout	86	172
14	Atlantic salmon	1	11
15	Brown trout	23	64
16	Brook trout	16	69
17	Lake trout	18	0
18	Rainbow smelt	0	1
19	Chain pickerel	16	58
20	Northern pike	61	45
21	Muskellunge	20	3
22	Carp	134	356
23	Fathead minnow	7	10
24	Longnose sucker	3	6
25	White sucker	40	96
26	Smallmouth buffalo	43	43
27	Bigmouth buffalo	16	25
28	Black bullhead	72	41
29	Yellow bullhead	62	36
30	Brown bullhead	55	55
31	Channel catfish	151	174
32	White bass	58	87
33	Striped bass	5	24
34	Green sunfish	102	76
35	Bluegill	240	162
36	Smallmouth bass	35	138
37	Largemouth bass	264	134
38	White crappie	125	73
39	Black crappie	139	84
40	Yellow perch	52	58
41	Sauger	20	54
42	Walleye	76	91
43	Freshwater drum	73	184
44	Steelhead trout	0	12
45	Kokanee salmon	19	5
46	Steelhead trout	0	185
47	Bonytail chub	8	11
48	Humpback chub	0	2
49	Colorado squawfish	1	7
50	Speckled dace	0	17

TABLE 19. EXAMPLE OF TOTAL NUMBER OF RECORDS BY STATION

Tables 6 = MSTPM6+MSTRM1

Station	No. of T-Records	No. of F-Records	Number of F-T Data Sets
10200	0	0	0
20100	630	1973	25
20200	38	23	10
20300	17	27	7
20400	25	19	12
20500	17	420	3
20501	5	25	1
20700	28	59	3
20800	42	137	5
20900	115	3326	10
21000	57	30	3
21100	23	20	1
21200	2	23	2
21500	6	135	2
21600	12	160	4
21800	31	406	8
21900	146	357	5
22000	36	533	3
22100	4	61	1
22101	3	36	1
22200	4	21	1
22300	3	16	1
22400	3	6	1
22500	3	8	1
22600	5	2	1
22700	2	3	1
30000	0	0	0
30200	0	96	0
40600	87	73	3
40601	95	60	2
40700	177	0	0
40800	0	0	0
40900	177	10	0
50000	0	0	0
50100	345	1262	16
50200	780	1887	16

Table continues - but not included.

be determined throughout the United States. Continual updating of the data base would supplement current information and the disappearance of fishes within zones could be assessed. Also, as sampling and reporting procedures become more standardized, fish species that appear to be absent from particular river basins will be catalogued into the data base and thus allow more meaningful correlations for analysis.

At first glance, it could be assumed that for each species in a particular water body, Table 15 indicates the fish sampling gear most commonly used in conjunction with specific water temperature sampling equipment (TSE) for the particular thermal characteristics (TC) of the water body. For the most part, these types of correlations should be cautiously related and carefully qualified.

For instance, fish sampling is rarely done in exactly the same place of known temperature monitoring stations. Thus these two types of data may be collected miles apart. The exceptions to this occur in anadromous fish management programs where the two types of data are collected simultaneously. These two types of information appear together in Table 15.

An additional caution to the user of this table is in the interpretation of the thermal characteristic (TC) column. The TC category coded number "1" (stratified) might be assumed to be a lake environment, while number "2" (isothermal) is logically related to a stream environment. However, not all lakes are stratified, and not all streams are isothermal. The Mississippi River offers a good example of this phenomenon as it alternately changes character from one pool to another. Furthermore, many sampling agencies failed to report the known TC of water-bodies, and in many cases samples were taken from the surface only. Thus, as is apparent from the table, it was difficult to determine this category from the literature and many of the data were encoded in category 3 (not given).

Table 16 provides an indication of the total number of fish-temperature data sets occurring within the data base by temperature sampling equipment and thermal characteristic. Table 17 represents the total number of F/T data sets by fish-count sampling method and the thermal characteristics for all species and all stations. It should be noted that Tables 16 and 17 will not necessarily have an equal number of F/T data sets. For a given station and year of record, there may have been one or more different types of fish sampling methods utilized. However, for that same station and year perhaps only one type of temperature sampling equipment was used; of course, the reverse can also be true; and therefore, the total F/T sets in the two tables are not expected to be equal.

Fish count sampling method "weir" (category 3) and "ladder" (category 6), on the S-R listing (category 2), are closely associated and commonly used together. These types of capture methods are most often used in counting migrant fish populations in cold, isothermal streams as is apparent from Table 15. If these two categories were merged, they would yield the highest number of F/T data sets by any one fish count sampling method. Again, this can be directly attributed to water temperature measurements being collected as a standard procedure with migrant fish populations research.

Included in data from the complete table (see Table 26) for the example given as Table 19 is a listing of the total number of temperature records and total number of fish records available at each station for all years of record. The program logic which develops this table defines a F/T data set as an occurrence of both fish and temperature data for at least one month within any year of record. Since this table will produce statistics for all species on record, the storage requirements do not allow sorting by species within each year of record and each station.

The usefulness of this table is not in its tabulation of F/T data sets at each station but rather in its indication of the actual amount of records available at each station. A record is defined as an 80-column card of either fish or temperature data on an encoding data-sheet. Therefore, the reason that fish records in this table outnumber temperature records for many stations is that every card of fish records is one species only, whereas, one temperature record could be 30 daily entries, 12 monthly entries, or 4 seasonal entries.

It is apparent from this table that some stations have no fish or temperature records. The reason for this is that these are spawning-data-only stations. These stations are identified by an asterick (*) on the station list included in Appendix C of this report.

The tabulation of the number of fish-temperature data sets available for each species broken down into lake-reservoir and stream-river categories is included in Table 28 which is the complete data for the example given here as Table 18. Unidentified species, i.e., unidentified chub, etc., are not tabulated.

This table gives a clear indication of the species of fish that are preferentially sampled for their sport or commercial value. It also supports our findings that many of the fish that are captured are not documented in the literature, as in special single-species studies. It also documents that most sampling operations selectively avoid the smaller fish such as shiners, darters, and minnows.

Those species which show "0" F/T data sets in both categories indicate that for all years and all stations there were not matching months of data. However, the possibility exists that both types of data were collected, but at different times of the year, or that these data were collected in opposing years but were still included in the data base. This type of situation was very common with the integration of U.S. Geological Survey temperature data into the data base since these data were encoded independently of any fish data.

Computer Program WKTTAB

This program uses the FTT-tape to produce a table of minimum, maximum and mean temperatures and corresponding fish counts for a given species. WKTTAB uses as input the weekly fish-temperature tape created by FTT which uses as input the STWKLY tapes to produce the table illustrated in Table 20. The

TABLE 20. EXAMPLE OF OUTPUT FROM COMPUTER PROGRAM WKTTAB WHICH PRODUCES A TABLE OF MINIMUM, MAXIMUM AND MEAN TEMPERATURES AND CORRESPONDING FISH COUNTS

Pink Salmon						
Station	Year	Week	Maximum	Mean	Minimum	Fish
20100	35	1	31	31	31	-
20100	50	1	31	31	31	-
20100	49	1	32	32	32	-
20100	52	1	32	32	31	-
20100	38	1	32	31	31	-
20100	43	1	33	33	32	-
20100	45	1	33	33	32	-
20100	59	1	33	32	31	-
490100	59	1	33	33	32	-
20100	42	1	34	34	34	-
20100	39	1	34	33	32	-
20100	60	1	34	34	34	-
20100	55	1	34	33	33	-
20100	54	1	35	35	34	-
20100	58	1	35	34	33	-
20100	63	1	35	35	34	-
20100	62	1	35	35	34	-
20100	40	1	35	35	-1	-
20100	36	1	35	34	34	-
20100	48	1	35	35	34	-
20100	47	1	35	34	34	-
20100	46	1	36	35	35	-
20100	44	1	36	35	35	-
20100	61	1	37	37	36	-
20100	53	1	37	37	36	-
20100	37	1	-1	32	32	-
20700	64	1	-1	35	-1	-
540101	65	1	-1	38	-1	-
540101	51	1	-1	41	-1	-
540101	40	1	-1	43	-1	-
540101	56	1	-1	36	-1	-
540101	55	1	-1	39	-1	-
540101	54	1	-1	42	-1	-
540101	53	1	-1	40	-1	-
540101	52	1	-1	34	-1	-
540101	64	1	-1	43	-1	-
540101	63	1	-1	43	-1	-
540101	62	1	-1	42	-1	-
540101	61	1	-1	39	-1	-
540101	59	1	-1	40	-1	-
540101	58	1	-1	40	-1	-
540101	57	1	-1	39	-1	-
540102	67	1	-1	43	-1	-
540102	64	1	-1	43	-1	-
540102	66	1	-1	41	-1	-
540102	60	1	-1	39	-1	-

data is sorted in ascending order by week, maximum temperature, and year. A binary sort is used so that -1's (indicating no data), having a one in bit zero of the computer word for the sign appear at the bottom of each sort. The algorithm used to produce the table is as follows: A species number is input to the program and the species name printed at the top of each page, in the case of this example, pink salmon (Oncorhynchus gorbuscha). The input tape is then searched for yearly station blocks containing pink salmon catch records. Each time one is found all the weekly temperature and weekly fish records for that station during that year are read into a buffer. When an end-of-file is encountered on the tape, the above mentioned sort is performed on the records in the buffer and the contents of the buffer are printed out. If a "_" appears in the "fish" column, this indicates that the species in question was caught at the station during that year, but not during that week. If fish were captured during the same week, the number caught appears in the "fish" column. The complete table would continue through all fifty two weeks.

Computer Program WKTPLT

WKTPLT is a companion program to WKTTAB in that it presents the same data in a graphical rather than tabular form. The logic of this routine will cause an "X" to be printed (plotted) where both a temperature and a fish catch record for a given species occur in the same week. A second option is provided that will plot an "X" for any week that a temperature was recorded and the species was found at that station sometime during the same year. The first option (Figure 3) corresponds to WKTTAB where a number is found in the "fish" column. These envelopes can be produced for each species for maximum and minimum as well as mean (example given) temperatures. They are useful in that extreme temperature preferences of a given species (as indicated by their presence) can be determined as well as a temperature envelope. However, these values are not weighted and a given record (i.e., an "X" at a particular temperature in a given week) may represent one or many records. Figure 4, which is the second option of WKPLT, illustrates the mean temperature data in the table produced by WKTTAB.

Computer Program WKPCT1

This program obtains data from the weekly fish-temperature tape made by Program FTT and produces a tape containing cumulative percentiles of weekly average temperatures at one degree increments for all species designated. Printer output is also generated. Categories are mean and maximum temperatures for fish catch records occurring in the same year and in the same week as temperature measurements were taken (Table 21). This and the following table are only partial tables for one species. The complete tables for each species would continue for 52 weeks.

Computer Program WKPCT2

This program reads the percentile tape produced by WKPCT1 and generates user-specified interpolated percentile values for user-specified species and weeks. Data printed in Table 22 are interpolated mean and maximum

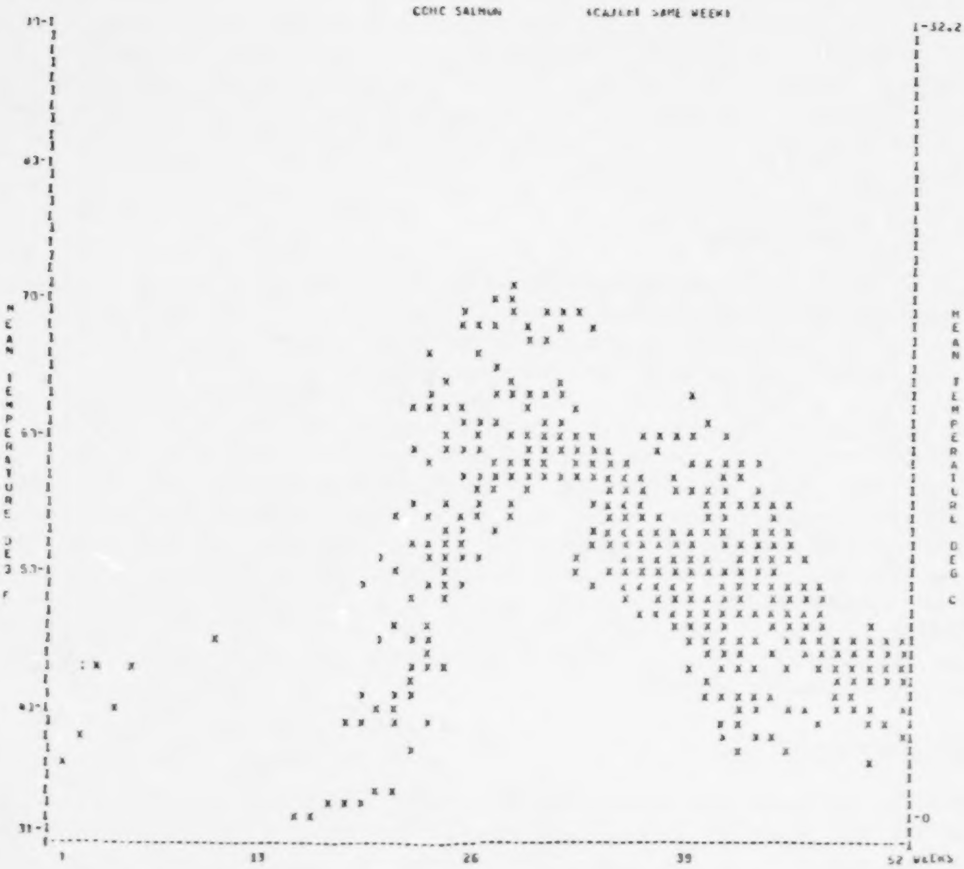

Figure 3. Example of computer output from computer program WKTPLT, Option 1, (see text).

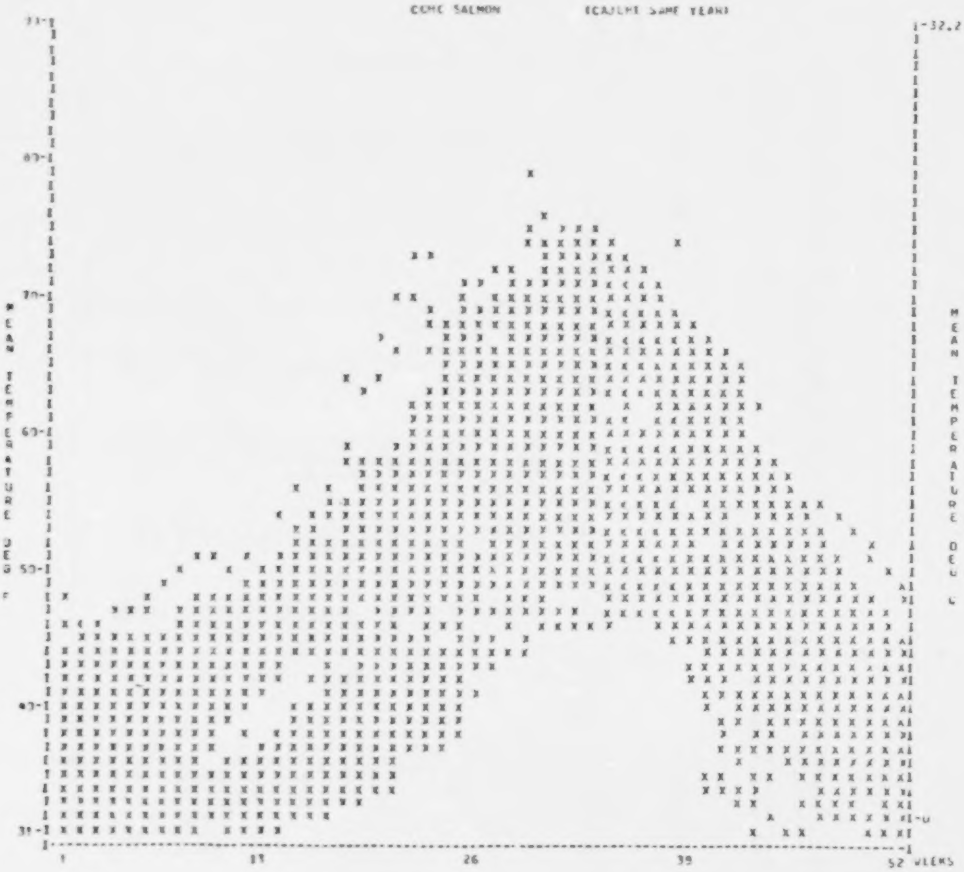

Figure 4. Example of computer output from computer program WKTPLT, Option 2, (see text).

TABLE 21. EXAMPLE OF COMPUTER OUTPUT FROM COMPUTER PROGRAM WKPCT1 WHICH PRODUCES CUMULATIVE PERCENTILE OF WEEKLY TEMPERATURES FOR A GIVEN SPECIES

```
                                      Chinook Salmon      Week 1                               103

                         Same Year                                                  Same Week

              Max                            Mean                           Max                            Mean

Temp   Freq  N(T)  Prcntl    Temp   Freq  N(T)  Prcntl    Temp   Freq  N(T)  Prcntl    Temp   Freq  N(T)  Prcntl

31.0     0     0      0.     31.0     1     1      1.     31.0     0     0      0.     31.0     0     0      0.
32.0     1     1      1.     32.0     1     2      2.     32.0     0     0      0.     32.0     0     0      0.
33.0     2     3      4.     33.0     2     4      3.     33.0     0     0      0.     33.0     0     0      0.
34.0     1     4      6.     34.0     7    11      9.     34.0     0     0      0.     34.0     0     0      0.
35.0     3     7     10.     35.0     1    12      9.     35.0     0     0      0.     35.0     0     0      0.
36.0     2     9     13.     36.0     6    18     14.     36.0     1     1      7.     36.0     1     1      7.
37.0     2    11     15.     37.0     4    22     17.     37.0     0     1      7.     37.0     0     1      7.
38.0     1    12     17.     38.0     8    30     23.     38.0     0     1      7.     38.0     0     1      7.
39.0     9    21     29.     39.0    13    43     34.     39.0     0     1      7.     39.0     0     1      7.
40.0     6    27     39.     40.0    16    59     46.     40.0     0     1      7.     40.0     0     1      7.
41.0    11    39     53.     41.0    17    76     59.     41.0     0     1      7.     41.0     0     1      7.
42.0    10    48     67.     42.0    17    93     73.     42.0     0     1      7.     42.0     0     1      7.
43.0     4    52     72.     43.0    11   104     81.     43.0     1     2     14.     43.0     1     2     13.
44.0     1    53     74.     44.0     5   109     85.     44.0     0     2     14.     44.0     0     2     13.
45.0     3    56     78.     45.0     3   112     98.     45.0     1     3     21.     45.0     1     3     20.
46.0     3    59     82.     46.0     5   117     91.     46.0     1     4     25.     46.0     4     7     47.
47.0     5    64     89.     47.0     5   123     96.     47.0     4     8     57.     47.0     4    11     73.
48.0     6    70     97.     48.0     3   126     98.     48.0     4    12     86.     48.0     2    13     87.
49.0     0    70     97.     49.0     1   127     99.     49.0     0    12     86.     49.0     1    14     93.
50.0     1    71     99.     50.0     0   127     99.     50.0     1    13     93.     50.0     0    14     93.
51.0     1    72    100.     51.0     1   129    100.     51.0     1    14    100.     51.0     1    15    100.
```

TABLE 22. EXAMPLE OF COMPUTER OUTPUT FROM COMPUTER PROGRAM WKPCT2 WHICH GENERATES TABLES OF SELECTED PERCENTILES FOR GIVEN SPECIES BY WEEK

```
                                Chinook Salmon

                   Max Temp                                 Mean Temp

           Temp   Freq    N(T)    Prcntl           Temp   Freq    N(T)    Prcntl
Week 1
           33.60    0       3       5.00           33.34    0       6       5.00
           35.10    0       7      10.00           35.13    0      12      10.00
           38.27    0      14      20.00           37.45    0      25      20.00
           39.10    0      21      30.00           38.65    0      38      30.00
           40.16    0      28      40.00           39.51    0      51      40.00
           40.82    0      36      50.00           40.29    0      63      50.00
           41.52    0      43      60.00           41.05    0      76      60.00
           42.60    0      50      70.00           41.80    0      89      70.00
           45.53    0      57      80.00           42.85    0     102      80.00
           47.13    0      64      90.00           45.64    0     115      90.00
           47.73    0      68      95.00           46.77    0     121      95.00
           51.00    1      72     100.00           51.00    1     128     100.00

Week 2
           32.65    0       3       5.00           33.45    0       6       5.00
           36.32    0       7      10.00           35.28    0      12      10.00
           37.92    0      14      20.00           37.28    0      25      20.00
           39.41    0      21      30.00           38.34    0      38      30.00
           40.02    0      29      40.00           39.25    0      50      40.00
           40.58    0      36      50.00           39.92    0      63      50.00
           41.30    0      43      60.00           40.62    0      76      60.00
           42.39    0      51      70.00           41.45    0      88      70.00
           44.50    0      58      80.00           42.43    0     101      80.00
           46.34    0      65      90.00           45.05    0     114      90.00
           47.12    0      69      95.00           46.16    0     120      95.00
           52.00    1      73     100.00           51.00    1     127     100.00
```

Percentiles and N(T) values are extrapolated where a zero occurs in the frequency column.

temperatures for a given percentile of occurrence in the data base where a fish catch record occurred during the same year.

Computer Program STUDY1

This program will, on option, collect data from the Master Tape(s) and

(a) calculate and print monthly temperature data and one standard deviation for each year at each station,
(b) print monthly and/or annual fish count by species and by capture method for each year,
(c) print the percentage of total annual count that each species comprises for a given capture method, and
(d) write on tape MONTEMP for each station and each year, the average maximum, mean, and minimum monthly temperature.

STUDY1 output is shown in Table 23. The top part of Table 23 gives station name and number and monthly temperature data and statistics. Following that is yearly capture data by species and technique, e.g., in 1949, 101 threadfin shad (Dorosoma petenense) were caught by gillnetting (month unknown). Following are additional fish statistics. The number preceding the species name is the species number. The out-put tape of STUDY1 is used by the graphics program ECOPLOT.

DATA GRAPHICS

The present FTDM system produces a series of six-plot formats in any combination desired by the user. The data comprising these plots are provided by the output (tapes) of programs STWKLY and STUDY1, respectively. The sequence of operations and examples of the six graphic presentations are described in the following paragraphs.

Computer Program MPLOT

This program uses the summarized data from the Master Tapes to collect specified data for plotting (ECOPLOT). The input tapes to this program may be one or two of the following summary tapes depending on the data to be plotted:

(a) WKTAP (the accumulation made by program STWKLY of all weekly temperatures for each station by year),
(b) MONTAP (the accumulation made by program STUDY1 of all monthly temperatures for each station by year), and
(c) TOTFSH (the accumulation made by program STUDY1 of total fish count for each station by year).

The program writes an output tape, MASTER, which is read directly by ECOPLOT. Computer cards input to this program supply the information necessary to define the type of plot to be generated - stations, years, and any other necessary information for the data collection. Annotation information can be supplied at the time of actual plotting.

TABLE 23. EXAMPLE OF COMPUTER OUTPUT FROM STUDY1 WHICH PRODUCES FISH TEMPERATURE STATISTICS FROM MASTER TAPES

```
Station 260101    River Mile 21.5, St. Croix River, WI          Date 030672    Year 1949      Page 38

                           Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec      Y2
  Av.Min Temp             -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0
  Av.Max Temp             -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0
  Mean Temp               -1.0  32.0  -1.0  -1.0  60.7  65.4  72.5  77.6  70.2  52.4  -1.0  -1.0
  St.Dev - Min            -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0
  St.Dev - Max            -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0
  St.Dev - Mean           -1.0  -1.0  -1.0  -1.0   4.6   2.2   4.6   1.5   4.8   8.3  -1.0  -1.0

95 Pctconfidence
     Limits

       Lower              -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0
       Upper              -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0
       Lower              -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0
       Upper              -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0  -1.0
       Lower              -1.0  32.0  -1.0  -1.0  51.7  61.2  63.5  74.0  60.8  36.2  -1.0  -1.0
       Upper              -1.0  32.0  -1.0  -1.0  69.7  63.7  81.5  80.5  79.7  68.6  -1.0  -1.0
Threadfin Shan   Gilnet    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.      101.
Mooneye          Gilnet    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.        1.
Mooneye          Creel     0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.        6.
Shortnose Gar    Gilnet    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.        2.
Shortnose Gar    Trawl     0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.        1.
Freshwater Drum  Gilnet    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.       18.
Freshwater Drum  Creel     0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.      132.
Freshwater Drum  Trawl     0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.    0.      365.
      CONTINUES FOR OTHER FISH SPECIES
```

```
 Capture          Total            Species            Percent of Total
 Method           Count                                 Annual Count

 Gilnet           314.0        4  Threadfin Shad           32.803
                              20  Northern Pike              .637
                              22  Carp                      1.274
                              31  White Bass                3.185
                              32  Striped Bass             25.470
                              35  Black Crappie             2.548
                              39  Black Bullhead            2.229
                              40  Yellow Perch              7.325
                              41  Sauger                   13.376
                              42  Wallye                    1.592
                              43  Freshwater Drum           5.732
                             118  Mooneye                    .318
                             138  Golden Redhorse            .318
                             161  Shortnose Gar              .637
                             162  Spotted Sucker             .637
                             165  Silver Redhorse            .637
                             170  Shrthd Redhorse (N)       1.274
 Creel           1085.0
                              20  Northern Pike              .553
                              26  Smallmouth Buffalo       12.166
                              31  White Bass                 .553
                              32  Striped Bass               .184
                              34  Bluegill                  5.899
                              35  Smallmouth Bass          14.470
                              36  Largemouth Bass            .367
                              40  Yellow Perch             40.922
                              41  Saugen                     .276
                              42  Walleye                   5.438
                              43  Freshwater Drum           5.530
                              78  Unk   Bullhead            1.014
                             165  Silver Redhorse           1.751
                             170  Shrthd Redhorse (N)        .276
                             173  Logperch                   .092
                             174  Silver Chub                .092
                             175  Silver Lamprey             .869
                             177  Unk   Buffal              9.954
                             179  Cal. Udlfsh (Garf)         .092
      CONTINUES FOR OTHER CAPTURE METHODS AND SPECIES
```

Program MPLOT searches the tapes for specific stations and years. The data are checked and desired calculations are performed before writing out the plot tape. During this search and write phase of operation, every effort is made to continue the run, despite missing data or other data anomalies. When data for any particular station or year cannot be found, an error-message is printed out. Hence, after user inspection, any data set found to be inadequate or unacceptable can be deleted by the plotting program.

Each data set is identified by graph type, stations and years, and composite plots are given a special identification number to aid in accumulating the necessary data being used for these plots. A 72-character title is output as the first record on the plot tape and is produced as part of the graphics set for filing identification.

Output from MPLOT1 is outlined as follows and is shown in Table 24. For plot 1 in Table 24, at the top, the station requested is 250100, from 1948 to 1962. There are three species of trout present, 77.55% brook (*Salvelinus fontinalis*), 19.98% brown (*Salmo trutta*), and 2.46% rainbow. The total catch for the period considered is 14849,

Plot No. 1 — (See above and Table 24)

- (a) Station name,
- (b) First and last year,
- (c) Number of species,
- (d) Names of species, and
- (e) Total and percent of each species.

Plot No. 2 — (Table 24)

- (a) Station name,
- (b) First and last year and number of years,
- (c) Number of species,
- (d) Names of species, and
- (e) For number of years given:
    - (1) Year
    - (2) Total and percent of each species.

Plot No. 3 -- (Table 24)

- (a) Station name,
- (b) First and last year and number of years, and
- (c) For number of years given:
    - (1) Yearly and monthly temperatures.

Plot No. 4 — (Example not given)

- (a) Station name,
- (b) Number of abundant and scarce species,

TABLE 24. EXAMPLE OF COMPUTER OUTPUT FROM MPLOT1 (SEE TEXT)

```
Plots 1, 2, and 3                                    Date 030372      Page 47

                 410 records copied to drum file  ID
                last record on drum is all 999999's

Input 250100    Pigeon River trout research station, MI.
Input year  48  62

      Pigeon River trout research station, MI.
      1948  1961
         3
          3
Brook trout
Brown trout
Rainbow trout
        14849.00
  .7755    .1998    .0246
.END..

Input 260101    River mile 21.5, St. Croix River, MN.
Input year  67  71
       1
        River mile 21.5, St. Croix River, MN.
       1967  1970       0
         26
           26
Freshwater drum
White bass
Sauger
Unk. Crappie
Threadfin shad
White crappie
Black crappie
Trout perch
Carp
Walleye
Logperch
Unk. shiner
Channel catfish
Silver redhorse
Smallmouth bass
Yellow perch
Bluegill
Shorthead redhorse (NRTH)
Lake sturgeon
Shortnose gar
    CONTINUES FOR OTHER SPECIES AND YEARS
```

Table continues - but not included.

(c) Names of above species,
(d) Year,
(e) Weekly temperatures, and
(f) Monthly temperatures.

Plot No. 5 — (Example not given)

(a) Species and abundance,
(b) Number of stations,
(c) Names of stations,
(d) First and last year of each station, and
(e) Weekly temperatures.

Plot No. 6 — (Example not given)

(a) One species,
(b) Number of stations,
(c) Names of stations,
(d) First and last year of each station,
(e) Weekly temperatures, and
(f) Abundance and spawning ranges.

Computer Program ECOPLOT

The graphics program, ECOPLOT, processes the plot tape generated by MPLOT to produce as many as six types of labeled and annotated graphs. An input card giving type of graph, identifier station, years of record and other annotated information is supplied for each graph requested. The plot tape is searched for the specific data set to be displayed, and the proper record is found, control is transferred to the subroutine GRAPHS which accomplishes the plotting. Options are included to allow for rewinding of the plot tape and to switch tape drive units as required. Hence, more than one master may be processed per run, and data need not be plotted in the same order as on any one plot tape. Each plot run is identified with a run number, data, and title of plot tape used.

Brief descriptions of graphs generated by types follow:

(1) A plot displaying weekly and monthly average minimum, maximum, and mean temperatures may be output for each station and year and for as many as six abundant and scarce species. At present, the species data are input for each plot (Figure 5).
(2) A sinusoidal-type of plot showing monthly average minimum, maximum, and mean temperatures for selected stations, and for 10 year periods is produced if requested (Figure 6).
(3) Weekly average minimum, or mean temperature ranges are displayed as bell-shaped curves where a given species is abundant or scarce (Figure 7).
(4) A composite weekly-average temperature plot of averaged minimum, maximum, and mean temperatures is produced for as many as 10 stations and for selected years when the species are observed

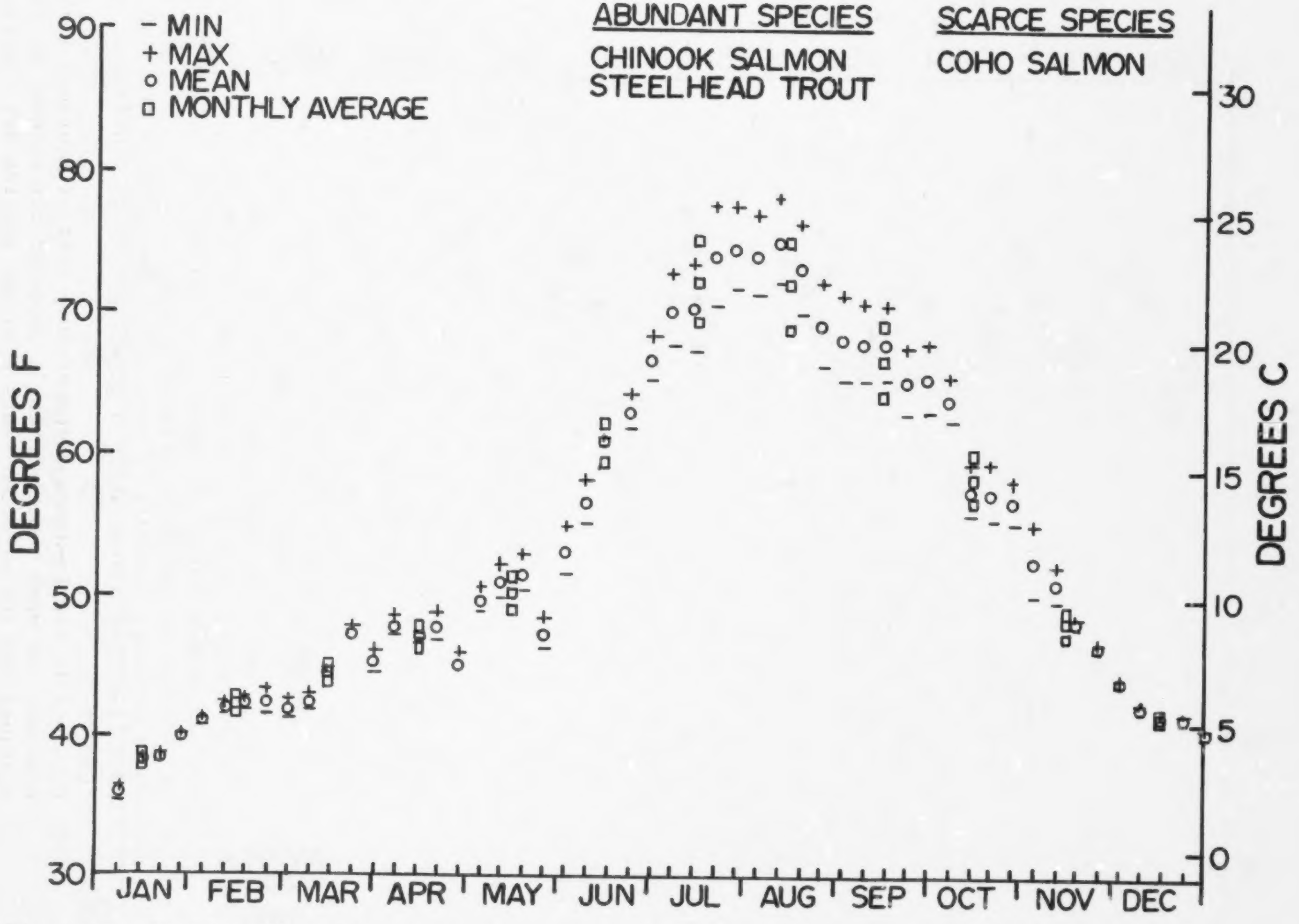

Figure 5. Weekly and monthly temperatures at the Lewiston fish trapping facility.

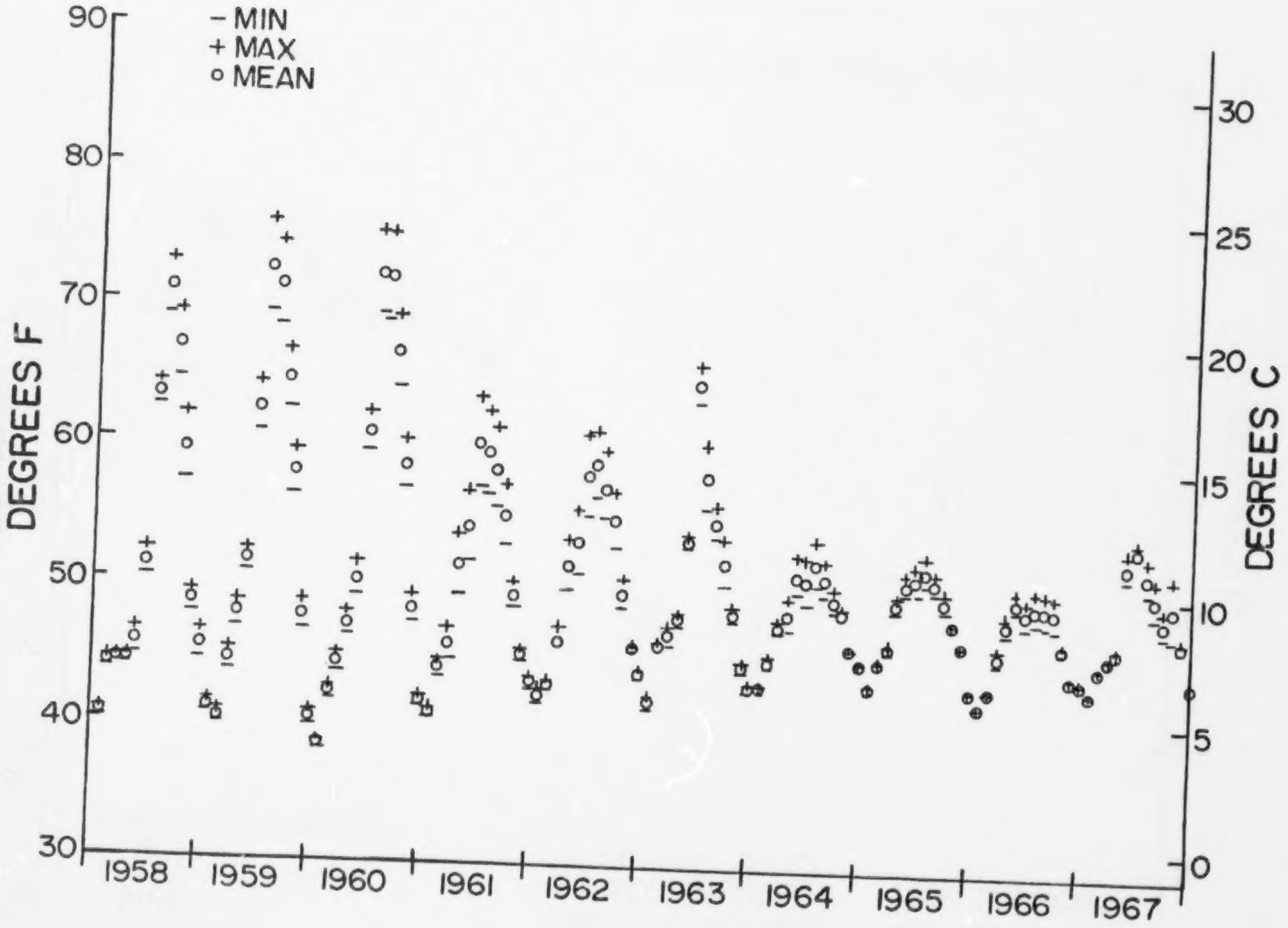

Figure 6. Average monthly temperatures at the Lewiston fish trapping facility.

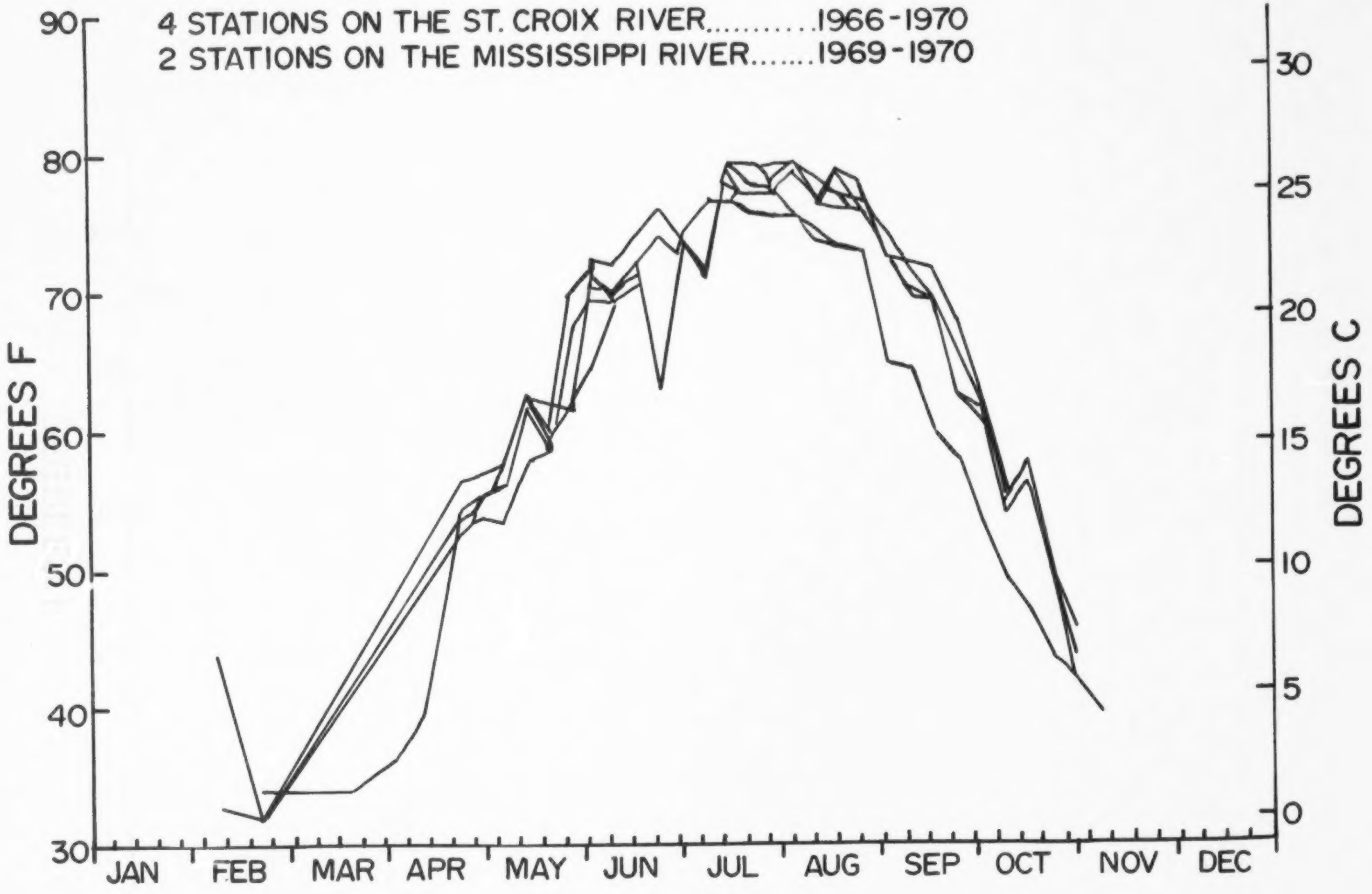

Figure 7. Weekly mean temperature for yellow perch where it is abundant.

to be abundant. Stations and years to be averaged are supplied as input by the user. Spawning dates, temperature ranges, and intervals of species abundance are displayed in the body of the graph (Figure 8).

(5) A fish population distribution percentage histogram is produced for any requested station and for any given year of record. The species names are listed in order of abundance (Figure 9).

(6) A summary histogram of the annual relative abordance of selected fish species for any given station, and as many as five species is also a user option. Species are displayed in order of abundance, and any species amounting to less than 1 percent of the annual count is not displayed (Figure 10).

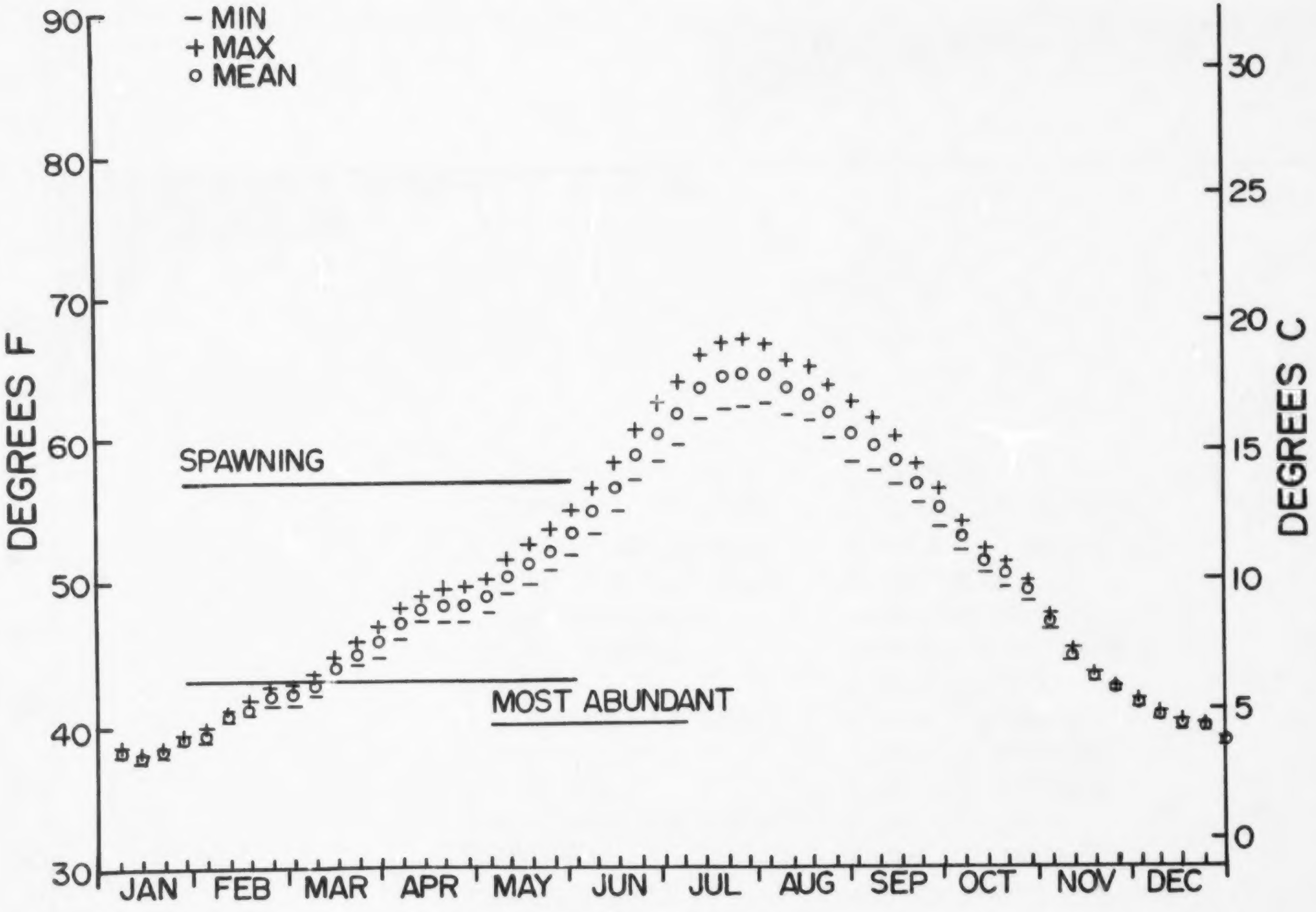

Figure 8. A composite weekly temperature graph for rainbow trout.

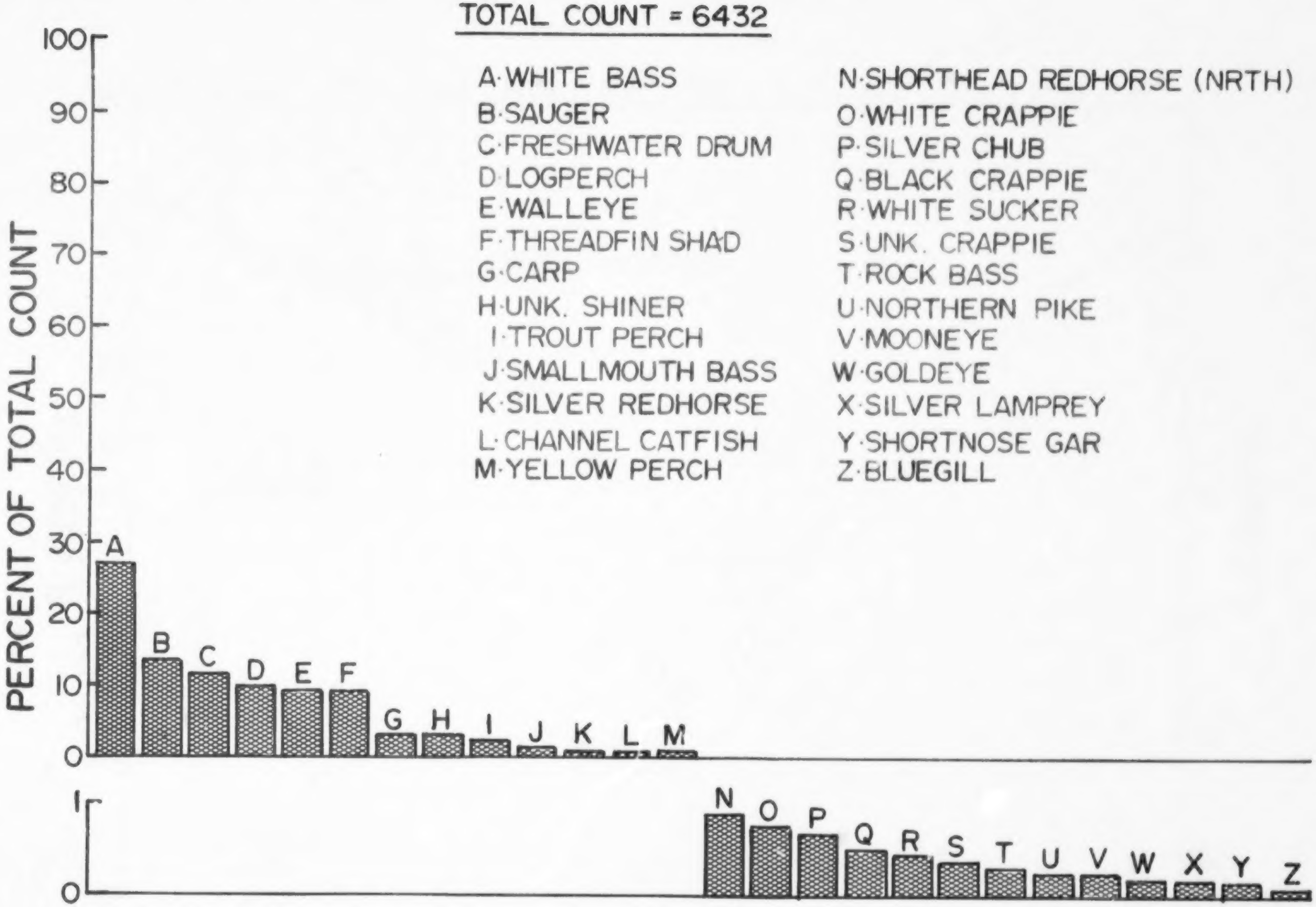

Figure 9. Relative abundance of the fish population at St. Croix River, Minnesota at River Mile 20.6.

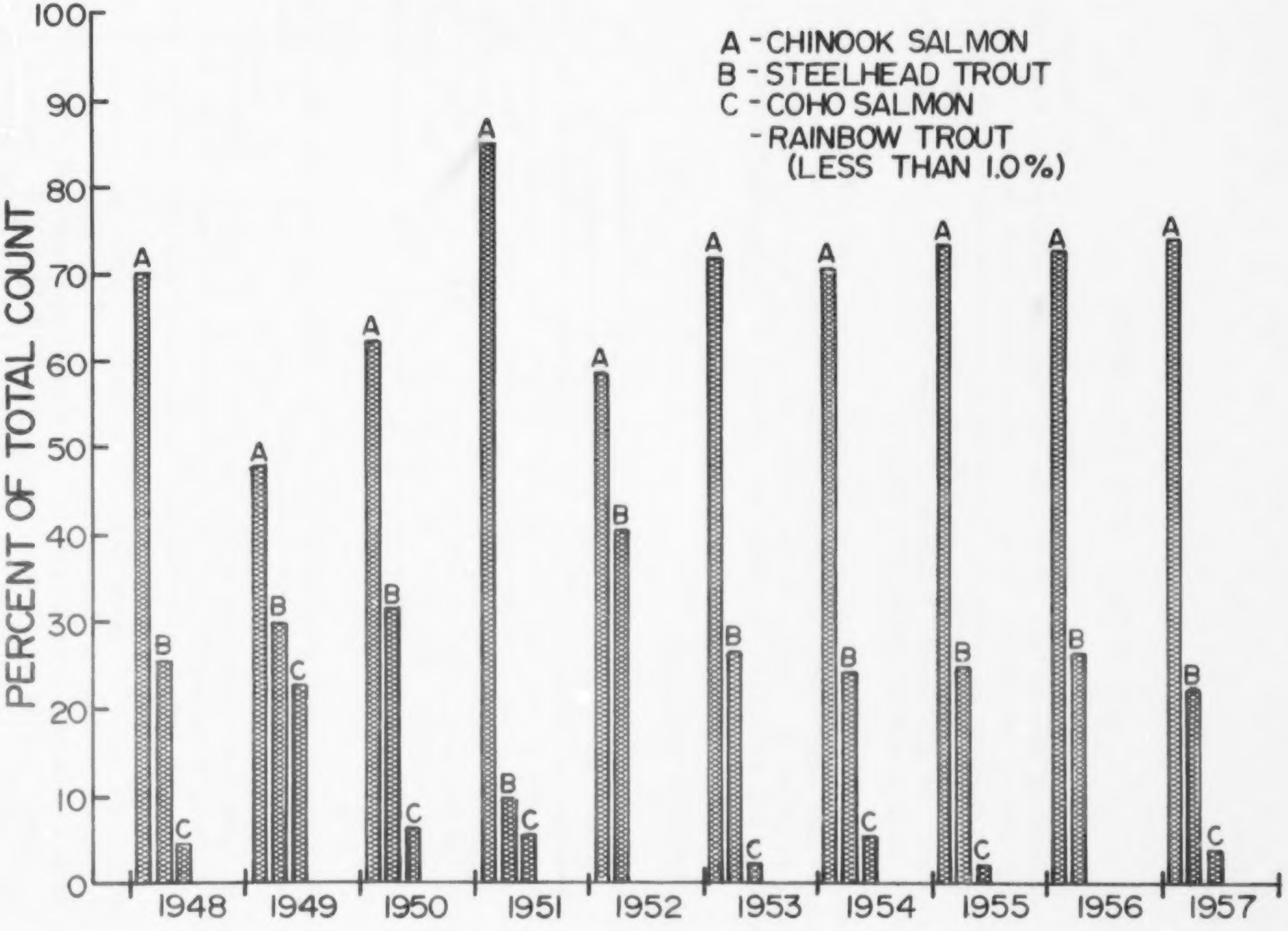

Figure 10. Annual relative abundance of selected species in Rogue River at Coldray Bar.

SECTION 5

DATA SOURCES, TYPES AND AMOUNTS

The purpose of this section is to provide a description of the sources, types and amounts of the various categories of fish and temperature data that were collected during the study. A partial list of the main sources of this information is contained in Appendix E. To facilitate discussion, the sources and types of fish data will be discussed first. Then, sources and types of temperature data are discussed, followed by a description of the amounts of both types of data gathered during the study.

Where possible, a brief review of the past history and present programs of each source are described. Since many of the freshwater fish management and research programs are supported by funds allocated from the Bureau of Sport Fisheries and Wildlife, it seems appropriate to begin the discussion here.

SOURCES AND TYPES OF FISH DATA

In 1956 the Fish and Wildlife Act created within the Department of the Interior the U.S. Fish and Wildlife Service, which was composed of the Bureau of Sport Fisheries and Wildlife (BSF&W) and the Bureau of Commerical Fisheries (BCF). This Act was in national recognition of the need for wise utilization of natural resources, both on land and in the oceans. Since that time, the marine activities of the BCF and BSF&W have been transferred to the National Marine Fisheries Service (NMFS) under the purview of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. The freshwater activities of the Bureau of Sport Fisheries and Wildlife have remained within the Department of the Interior.

In 1960, a cooperative program of training, investigation and application involving the BSF&W, State Fish and Game Departments, colleges, and universities was enacted under Public Law 86-686 (74-STAT.733). Under this law, Cooperative Fishery Units were instituted for the purpose of "facilitating cooperation between the Federal Government, colleges and universities, the states and private organizations for cooperative unit programs of research and education relating to fish and wildlife and for other purposes", (U.S. Department of Interior 1969). By 1972, 25 Units had been organized under the general guidance of a coordinating committee, representing the participating agencies. Fish information obtained from Cooperative Fishery Units was contained in unpublished theses, reprints and non-summarized raw data. Unit research programs are financed, in part, by the Division of Fishery Services of the BSF&W or by local fish and game commissions. The latter source usually contracts fishery research studies out to the Cooperative Fishery Units with

Federal Aid in Fish Restoration funds. Reports emanating from these studies are generally referred to as Dingell-Johnson (D-J) Progress Reports.

The Dingell-Johnson program was initiated in 1950 under the Federal Aid in Fish Restoration Act and receives funds through a manufacturer's excise tax on sport fishery equipment. Each state matches these funds from fishing and hunting license sales. The number of copies of D-J Reports produced by the fish and game commissions is at the discretion of each state agency; however, depending on the contents, at least one copy must be sent to each of the following: U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center (pesticide data), National Reservoir Research Program (reservoir data), and the Denver Public Library (all reports regardless of content).

The Denver Public Library, Library Reference Service, Federal Aid in Fish and Wildlife Restoration, which operates under contract with the BSF&W, was established in 1965 to assist individuals and organizations in obtaining Dingell-Johnson (sport fisheries) and Pittman-Robertson (wildlife) progress reports. State-by-state bibliographies and copies of D-J reports are available for a nominal fee. The Library Reference Service was a valuable aid in securing unpublished D-J reports for this study that could not be obtained from other sources.

In addition to funding and supervising a multiplicity of activities, the Bureau of Sport Fisheries and Wildlife conducts its own fishery research programs. One such program of the Division of Fishery Research is the National Reservoir Research Program which consists of the North Central and South Central Investigations Programs. Effects of different environmental variables on both standing crop and harvest of sport fishes have been studied on over one hundred reservoirs. Other areas of study are limnological trends and life history investigations on important fish species.

The National Marine Fisheries Service (NMFS) was also contacted during the survey to obtain fish-temperature data. In addition to "in-house" marine fishery research programs of this agency, cooperative research on rivers and reservoirs is also conducted in conjunction with individual states. An example of this type of program is the research conducted on problems of passage of salmon at dams on the Columbia River with the states of Washington and Oregon. The Columbia River research is conducted under contract with the NMFS's Fish-Passage Research Program which is supported by funds allocated from the Saltonstall-Kennedy Act of 1954. Information collected from this type of research is contained in the "Special Scientific Report--Fisheries", publication series.

Commercial catch records for major rivers and tributaries were obtained from the NMFS's Division of Statistics and Market News. Much of the catch data is summarized from data collected by other state agencies; for example, the Upper Mississippi River Conservation Committee (UMRCC) supplies the Mississippi River catch records by pool from Hastings, Minnesota, to Caruthersville, Missouri. The UMRCC was formed in 1943 by the action of the states of Illinois, Iowa, Missouri, Minnesota, Wisconsin, and the U.S. Fish and Wildlife Service for the purpose of investigating the fishery and wildlife resources of the Upper Mississippi River. Each state supplies the

UMRCC with commercial fish landing records, creel census records, and other types of fish population data compiled by fishery biologists within their area. Results are included in annual progress reports of the Fish Technical Committee of the UMRCC.

The U.S. Army Corps of Engineers (ACE) also contributed data for this study. For example, the Corps has, since 1938, recorded daily counts of fish passing over the dams along the Columbia and Snake Rivers. Although the main purpose of counting stations at fish ladders is to observe and appraise the effects of the dams on the anadromous salmon runs in the rivers, other fish species overreaching the dams, such as sturgeon, bass, etc., are also routinely counted. Ladder counts and daily water temperatures are presented from 1938-1969 in the Corps' "Annual Fish Passage Report, Columbia and Snake River Projects" (U.S. Army Corps of Engineers, 1969). Tables and graphs are given which include daily, monthly and yearly fish counts and water temperature along with other chemical and physical factors of the rivers.

An additional source of information on Columbia River fisheries was the Atomic Energy Commission (now Department of Energy, DOE) at Hanford. In 1944, the Atomic Energy Commission (AEC) began construction of a series of nuclear reactors on the Columbia River north of Richland, Washington. The number of reactors in operation since 1944 has ranged from as many as nine to the present two (Watson 1970). In the process of producing plutonium and electricity, water is extracted from the river, circulated through the reactors and returned to the river. Since the time that the reactors began operating, the AEC has continually sponsored research studies to determine the effects, if any, the effluent cooling water has on the Columbia River environment.

The results of these investigations, contained in AEC Research and Development Reports, have been utilized to obtain additional information on Columbia River temperatures and fish populations, especially salmon. Specific AEC research on the Columbia River environment included determining relationships of reactor operation and numbers of salmon spawning near Hanford (Watson 1970), correlation of water temperature to timing of seaward migration of juvenile chinook salmon (Becker 1970), evaluation of effects of heated effluents on fish survival (Becker and Coutant 1970), and effects of Hanford Plant operations on temperature of the river (Jaske and Synoground 1970).

In another region, the AEC at its Oak Ridge National Laboratories, conducted research in the area of thermal effects studies. One such study was monitoring, by use of an ultrasonic, temperature-sensing fish tag, the movement and temperature selection of largemouth bass in the Clinch River near Oak Ridge, Tennessee (Oak Ridge National Laboratory 1971).

In addition to contacting the agencies mentioned in the foregoing, each of the 49 state fish and game commissions were contacted to obtain a major portion of the fishery data. In general, fishery research and investigations carried on by the various state fish and game agencies are oriented towards a management approach to give the sports fisherman more recreation per dollar and at the same time ensure the survival and well-being of the multitude of game and nongame fish species. Most of these agencies rely upon Federal Aid in Fish and Wildlife Restoration Funds in order to continue their stream and lake management programs. Management information is generally summarized in Dingell-Johnson (D-J) Job Progress Reports which usually contain data on (1) life history studies, (2) creel census surveys, (3) rough fish eradication programs, (4) hatchery management programs,. and (5) limnological studies. Each of these is discussed briefly in the following paragraphs.

Life history investigations provide information on age and rate of growth, age composition, population dynamics, reproduction, food habits, distribution, and movement of fish. To obtain this type of information, fishery biologists carry on netting, seining, electro-shocking, trapping, and poisoning operations.

Creel census surveys generally provide information on fisherman use, harvest and tagging studies to determine stocking success. Essentially, a creel census is a standardized method by which an area of lake or stream is canvassed to contact anglers to determine the species composition of their catch. Summary evaluations of data collected during creel surveys might include: (1) residence of fisherman, (2) boat or shore fishing, (3) total hours fished, (4) total marked fish caught, (5) total unmarked fish caught, (6) total number of fishermen in census area, and (7) catch per angler hour for each species.

Rough fish eradication is generally initiated when it has been determined that the game-to-rough-fish ratio has become unbalanced in favor of nongame fish species. The use of rotenone is a popular method by which to attain the desired results. However, this method is relatively indiscriminate and many species of game fish are also killed. Restocking the particular water body with game fish acquired from local fish hatcheries is the final step in this type of program.

With each year passing, it has become evident that more sport fishermen are utilizing the nation's fishery resource and harvesting more fish than the fish populations can reproduce each year. Other factors such as pollution of waters, natural aging of reservoirs, and building of dams across rivers, have curtailed the ability of many fish species to naturally reproduce. As a consequence, fish hatcheries have been constructed to help reestablish the declining populations of fish. Hatchery programs include rearing of selected fish species for introduction into altered aquatic habitats such as trout into cold tailwater sections of streams below dams, restocking areas that have recently been under an eradication program as mentioned above, and for anadromous fish, maintaining trapping facilities on streams to capture adults during their spawning migration for egg taking purposes. The eggs are then incubated at the hatchery to insure higher survival of the young. As part of the latter program, water temperatures are monitored and numbers of each fish species entering the trapping facility are tabulated.

Information from limnological studies is generally included in three categories; (1) physical properties such as water transparency (or the amounts of dissolved and suspended materials), stream flow, and temperature; (2) chemical properties such as acidity, alkalinity, conductivity, carbon dioxide, pH, and dissolved oxygen; and (3) biological characteristics such as analysis of plankton, benthos, insects, and other organisms. Of these types of data, temperature is the most useful for the present study; however, additional information regarding such factors as pollution, flooding, habitat alteration, and food supply, etc., have been utilized to evaluate a particular body of water in terms of qualifying the fish-temperature data.

SOURCES AND TYPES OF TEMPERATURE DATA

The main sources of water temperature records were provided by the U.S. Geological Survey (USGS). Data collected from this agency were contained in a variety of publications which are listed in Appendix E. Prior to 1964, the USGS water quality data, which include records of either "spot" observations or tables of continuous daily records of maximum, mean or minimum temperatures, were compiled from fourteen major drainage basins within the United States. The data therein are listed in a downstream sequence, beginning at the headwaters. Each natural drainage area is called a "Part" and numbered from 1 through 14. From 1941 through 1963, the USGS annually published these data in water-supply papers entitled, "Quality of Surface Waters of the United States". Each of these volumes contains information on certain "Parts" or drainage basins. However, beginning with the 1964 water year (October 1 to September 30 of the following year), water temperature and related water quality data have been released by the Geological Survey in annual reports on a state-boundary basis.

Additional water temperature data were obtained from the Water Resources Data Center of USGS on a 9-track, 800 BPI, binary format, data tape. Since this is a fairly recent method of storing water quality data, time has not allowed for the historical backlog of all stations and all years of data referenced in USGS publications to be included on the tape.

Aside from compiling its own data, the USGS, by cooperating with a multiplicity of federal, state, and local agencies, obtains water quality information from almost every water-body in the country. As part of this cooperative program, the USGS co-publishes water temperature data for particular state needs. For example, the Montana Fish and Game Commission, in cooperation with the USGS, published a report in 1969 entitled, "Temperature of Surface Waters in Montana" (see Appendix E). This report provides for each station a graph on water temperature versus time, a table of spot observations ("Periodic measurements"), and, if available, tables of continuous records and summaries. Similarly, in 1966, the Tennessee Valley Authority (TVA) published "Water Temperature of Streams and Reservoirs in the Tennessee River Basin", which is a collation of published and unpublished data collected principally by themselves and the USGS in the four states adjoining Tennessee. Other states such as Texas, Oregon, Utah, and Missouri, for example, have published similar historical stream temperatures in cooperation with the USGS (Appendix E).

Where U.S. Geological Survey water temperature compilations were not available or not feasible to use because of their distance from a fish sampling location, other sources of water temperature records were sought out. Generally, state fish and game department files contain a fair amount of water temperature records ranging from raw data sheets to thermograph records and published tabulations. For the most part, these were collected on-site with fish population sampling programs such as at fish hatchery trapping facilities and on streams where creel surveys and such activities as gill-netting are performed. The latter two types of water temperature data are often included in Dingell-Johnson progress reports and characteristically represent daily, weekly, or monthly observations. Where lake temperatures were available, they were usually in the form of a monthly, quarterly, minimum/maximum surface, depth profile, or merely a graphical summary indicating "typical" temperature profiles for a stratified body of water.

The task of locating and obtaining "missing" temperature data for otherwise good fishery data sets was materially reduced through the use of the USGS "Catalog of Information on Water Data", (USGS 1970). This catalog is an index of information concerning water data acquisition activities of various state and federal agencies. Generally, water quality information for each location listed in the catalog includes the name of the reporting agency, agency station number, station name, latitude, longitude, state, county, period of record, storage of data, and types of data monitored. Actual data are not contained in the catalog, but must be obtained from the agency which collects the data. For example, the U.S. Army Corps of Engineers actively participates in monitoring water quality on major river systems such as the Mississippi, Cumberland, Ohio and Red River systems. These collected data are available upon request from the ACE.

An additional supplement to the USGS index is a catalog of maps which present, by station number, the geographical location of each station. Stations are grouped according to "geographic units" which are identified by basin code numbers. There are 79 geographic units, which for the most part coincide with and are included within the 14 major drainage basins previously explained. The stations within these geographic units are also numerically listed in downstream order.

Practically every agency involved in water resources has at one time or another compiled information on water temperature. For this reason only the agencies contributing the bulk of information have been discussed in this section; however, for the sake of completeness, the following is a brief list of sources of supplementary temperature data that were utilized in this study: U.S. Forest Service, EPA Water Programs Office (STORET data), Bureau of Reclamation, Bureau of Land Management, Bureau of Sport Fisheries and Wildlife, public utilities, and various state water quality agencies.

In summary, as was expected, a considerable amount of data was available to the study on fish population census and lake and stream water temperatures. However, it was an exception rather than the rule to find these two types of data collected together by the same agency at the same location and during the same time period. Therefore, the initial efforts of this study were to piece the two types of data together by location and time period, which had been collected from the various sources supplying the information.

THE AMOUNT OF ENCODED FISH-TEMPERATURE DATA

From a total of 2817 documents collected during the study, 574 stations were encoded by staff members in which both fish and water temperature data were assessed as compatible data sets. A list of all fish-temperature stations encoded is contained in Appendix C. The total number of documents that were collected in each of the 49 states surveyed (Table 25) is an indication of the general type of information obtained and the number of fish-temperature stations completed. It should be noted that a single document may contain information on any number of streams or reservoirs as, for example, a USGS publication on water temperatures for a particular state. In the column on "fish and/or temperature information", the number of documents is not an index of collated fish-temperature data sets; rather, it shows the total number of documents that contain either fish data or temperature data. The column on "other related information" pertains to supporting data on water resources and biological research that was not of direct use to this study.

As each document was reviewed, it was stamped with an accession number and cross-referenced with a bibliographic card. The personal knowledge gained in collecting the various types of data enabled each staff member to maintain a high level of quality control in selecting and encoding only those data containing information required for this study.

Although only 50 fish species were specified for indepth analysis, data on an additional 301 species defined as being of lesser economic or social importance have been included in the data base for future reference. However, 38 of these fish species were inadequately identified as to common or scientific name and, consequently, were encoded as unidentified trout, minnow, etc. A complete listing of the species encoded is contained in Appendix A.

Study results indicate that each set of fish-temperature data should be accompanied by a list of the literature references that contain either original data or information that further describe particular aspects of the data. Thus, observed changes in the fish populations or thermal regimes, as plotted from the historical data, can be evaluated in terms of all of the supporting publications and available knowledge regarding a specific area or environment. Ideally, a computerized bibliography of all literature collected would accomplish the foregoing goals; however, since this was beyond the original scope of the study, only a partial listing of 393 main sources of information is available (Appendix E).

The number of temperature records, fish records and fish-temperature data sets by station presently encoded in the data base for streams and rivers is given in Table 26. This information for lakes and reservoirs is given in Table 27. Even a cursory examination of these tables shows that there are many more temperature and fish records than there are matching fish-temperature data sets where both types of information were collected at the same time. However, it is hoped that users of the data base will use the temperature and fish records independently as well as combined. A possible use for a fishery biologist, for instance, could be to chronicle changes in species

TABLE 25. AMOUNTS OF DATA COLLECTED AND STATIONS ENCODED BY STATE

State	Total documents	Documents with fish and/or temperature information	Documents with other related information	Fish-temperature stations completed
Alabama	7	5	2	5
Alaska	76	45	31	33
Arizona	72	66	6	7
Arkansas	78	38	40	11
California	50	44	6	19
Colorado	25	17	8	10
Connecticut	8	4	4	4
Delaware	0	0	0	0
Florida	52	22	30	16
Georgia	6	5	1	0
Idaho	61	51	10	10
Illinois	72	42	30	23
Indiana	13	10	3	0
Iowa	21	16	5	14
Kansas	90	69	21	17
Kentucky	65	38	27	16
Louisiana	56	33	23	29
Maine	159	60	99	4
Maryland	12	11	1	9
Massachusetts	5	5	0	8
Michigan	158	101	57	8
Minnesota	46	35	11	31
Mississippi	45	43	2	20
Missouri	5	5	0	13
Montana	11	8	3	8
Nebraska	49	36	13	5
Nevada	107	100	7	25
New Hampshire	50	28	22	6
New Jersey	12	8	4	11
New Mexico	17	7	10	2
New York	85	33	52	15
North Carolina	46	29	17	22
North Dakota	50	42	8	0
Ohio	29	27	2	3
Oklahoma	72	46	26	8
Oregon	100	87	13	13
Pennsylvania	16	9	7	8
Rhode Island	11	3	8	3
South Carolina	26	21	5	9

(continued)

TABLE 25. (continued)

State	Total documents	Documents with fish and/or temperature information	Documents with other related information	Fish temperature stations completed
South Dakota	87	68	19	3
Tennessee	73	63	10	19
Texas	114	102	12	29
Utah	48	36	12	9
Vermont	41	36	5	3
Virginia	2	2	0	2
Washington	61	38	23	11
West Virginia	46	36	10	16
Wisconsin	156	107	49	29
Wyoming	14	5	9	8
National	120	50	70	0
Directory	6	0	6	0
Great Lakes	64	33	31	0
EPA Region I	10	8	2	0
EPA Region III	2	2	0	0
EPA Region IV	12	11	1	0
EPA Region V	6	5	1	0
EPA Region VI	5	2	3	0
EPA Region VIII	10	6	4	0
EPA Region X	77	46	31	0
Totals	2817	1905	912	574

TABLE 26. THE NUMBER OF TEMPERATURE RECORDS, FISH RECORDS, AND FISH-TEMPERATURE DATA SETS BY STATION, FOR STREAMS AND RIVERS

Station*	Number of records		Number of fish-temperature data sets	Station*	Number of records		Number of fish-temperature data sets
	Temperature	Fish			Temperature	Fish	
10200†	0	0	0	50000†	0	0	0
20100	630	1973	25	50100	345	1262	16
20200	38	23	10	50200	780	1887	16
20300	17	27	7	50300	83	721	6
20400	25	19	12	50600	53	171	9
20500	17	420	3	50700	90	721	5
20501	5	25	1	51000	22	310	6
20700	28	59	3	51200	4	51	1
20800	42	137	5	51500†	0	0	0
20900	115	3326	10	52700	84	302	5
21000	57	30	3	52800†	0	0	0
21100	23	20	1	70000†	0	0	0
21200	2	23	2	70501	1	12	0
21500	6	135	2	70900†	0	0	0
21600	12	160	4	80000†	0	0	0
21800	31	405	8	80100	24	481	7
21900	146	357	5	80300†	0	0	0
22000	36	533	3	100000†	0	0	0
22100	4	61	1	110100	23	0	0
22101	3	36	1	110200	61	189	2
22200	4	21	1	150400	334	328	8
22300	3	16	1	150500	182	175	0
22400	3	6	1	150600	37	302	5
22500	3	8	1	150900	71	336	5
22600	5	2	1	161200	148	235	5
22700	2	3	1	161201	148	289	7
30000†	0	0	0	161202	148	49	2
30200	0	96	0	161203	429	253	5
40600	87	73	3	161204	106	0	0
40601	95	60	2	161205	10	0	0
40700	177	0	0	161206	10	0	0
40800†	0	0	0	161207	128	0	0
40900	177	10	0	161300†	0	0	0

(continued)

TABLE 26. (continued)

Station*	Number of records		Number of fish-temperature data sets	Station*	Number of records		Number of fish-temperature data sets
	Temperature	Fish			Temperature	Fish	
161400†	0	0	0	201100	1	25	1
161500†	0	0	0	201200	1	16	1
180000†	0	0	0	201300	1	18	1
180200†	0	0	0	201400	1	18	1
180300†	0	0	0	210100	71	94	3
180400	205	116	6	210101	106	202	2
180401	151	123	7	210200	57	111	2
180402	151	221	7	210500	19	12	0
180403	151	121	5	210600	44	244	3
180404	148	81	5	210800	2	33	1
180405	148	166	5	210801	2	45	1
180406	148	93	5	210802	2	38	1
180407	148	96	5	210803	2	24	1
180500	205	116	1	210804	0	14	0
180600	122	0	0	210805	0	10	0
191200	131	4	1	210806	0	7	0
191300†	0	0	0	210807	0	39	0
191700†	0	0	0	210808	134	29	1
200300	179	94	3	210809	0	40	0
200301	179	153	10	210810	0	17	0
200400	0	25	0	210811	0	21	0
200401	0	14	0	210812	0	23	0
200402	0	14	0	210813	0	8	0
200403	0	24	0	210814	138	47	1
200404	0	20	0	211300	2	4	1
200500	24	23	1	211400	106	33	3
200600	16	29	2	222000†	0	0	0
200601	31	211	5	220200	362	114	12
200700	15	50	3	230000†	0	0	0
200800	11	36	4	230100	90	218	4
200900†	0	0	0	230500	51	88	1
201000†	0	0	0	230600	49	37	6

(continued)

TABLE 26. (continued)

Station*	Number of records		Number of fish-temperature data sets	Station*	Number of records		Number of fish-temperature data sets
	Temperature	Fish			Temperature	Fish	
230700	21	26	1	260600	0	114	0
230800	17	5	0	260700	187	0	0
230900	31	93	4	260701	44	0	0
240000 †	0	0	0	260702	44	0	0
240100	9	63	1	260703	59	0	0
240101	28	112	1	260704	14	0	0
240102	0	36	0	260705	44	0	0
240103	0	14	0	260706	45	0	0
240104	0	66	0	260707	36	0	0
240105	2	76	0	270300	12	8	1
240106	0	50	0	270400	12	19	1
250100	4	271	1	270600	5	24	1
250500	27	32	5	270601	6	16	0
260000 †	0	0	0	270700	14	18	1
260101	183	215	3	270701	5	15	0
260102	169	138	3	270800	9	19	1
260103	205	223	3	270801	9	12	1
260104	171	126	3	270900	10	18	1
260105	103	3	1	271000	9	17	0
260106	0	2	0	271100	10	32	1
260200	103	250	3	271200	9	22	0
260201	95	278	3	271201	10	22	1
260202	74	144	2	271300	9	23	1
260203	78	129	3	271400	179	199	3
260204	32	41	1	271401	122	202	3
260301	16	3	1	271500	177	64	7
260500	205	39	1	280000†	0	0	0
260501	205	81	5	280100	2	76	1
260502	205	98	6	280101	2	59	1
260503	45	38	1	280102	8	68	1
260504	36	29	0	280200	67	15	0
260505	202	48	1	280300†	0	0	0

(continued)

TABLE 26. (continued)

Station*	Number of records		Number of fish-temperature data sets	Station*	Number of records		Number of fish-temperature data sets
	Temperature	Fish			Temperature	Fish	
280400	148	96	5	330107	28	13	1
280401	148	89	5	330200	1	16	0
280402	148	109	5	330201	2	52	2
280403	148	112	5	340100	230	95	6
280404	148	102	5	350500†	0	0	0
280500	148	308	11	350600†	0	0	0
280600	207	0	0	350700†	0	0	0
290700†	0	0	0	351300	3	62	3
300000†	0	0	0	351301	3	65	2
300100	51	304	5	351302	3	75	3
300300	15	210	2	351303	3	53	2
300400	16	164	1	360000†	0	0	0
310000†	0	0	0	360200	3	51	1
311300	40	21	1	361000	48	24	1
311301	55	5	1	361001	29	25	1
311400	0	28	0	361201†	0	0	0
311401	0	14	0	361300†	0	0	0
311402	0	4	0	361400†	0	0	0
311500	0	52	0	380000†	0	0	0
320000†	0	0	0	380200†	0	0	0
320100	35	38	3	390700	36	77	2
320300	19	69	2	390701	36	68	1
320301	22	75	1	400000†	0	0	0
320302	16	75	2	400100	182	844	10
330000†	0	0	0	400200	11	165	1
330100	28	39	2	400300	70	65	4
330101	28	68	2	400400	261	69	12
330102	28	13	1	400500	83	4437	7
330103	28	57	2	400700	6	20	1
330104	28	36	2	400900	631	151	19
330105	28	29	0	401000	939	37	13
330106	28	35	2	401100	31	47	0

(continued)

TABLE 26. (continued)

Station*	Number of records Temperature	 Fish	Number of fish-temperature data sets	Station*	Number of records Temperature	 Fish	Number of fish-temperature data sets
401200	915	77	13	470600	4	14	0
410000†	0	0	0	470601	4	10	0
410100	3	68	3	470602	4	11	0
410101	0	17	0	470700	93	208	8
410102	3	99	0	470701	48	208	5
410103	3	76	2	470800	308	106	5
410104	2	63	2	480800	145	55	2
410105	1	79	1	480900	108	10	1
410106	1	34	0	482200	25	20	1
430000†	0	0	0	482201	0	13	0
430200†	0	0	0	482202	15	15	1
450000†	0	0	0	482203	0	13	0
450100	2	29	2	482204	41	7	1
450101	2	54	1	482205	118	1	1
450200	2	51	2	490100	65	537	4
450201	2	37	1	490101	275	1753	3
450300	4	0	0	490500	0	0	0
450400	1	0	0	490600	0	0	0
450500	6	0	0	500000	0	0	0
450600	3	0	0	500200	0	0	0
470200	179	68	4	510000	0	0	0
470201	179	0	0	510100	0	0	0
470300	9	176	2	540100	0	0	0
470401	207	167	5	540101	1295	3270	33
470402	229	0	0	540102	143	1480	13
470403	212	170	5	540103	0	225	0
470500	6	225	3	540104	279	1496	17
470501	0	223	0	540105	110	738	8
470502	6	227	2	540106	0	142	0

*Station locations are given in Appendix C.

†Spawning information only is available at these stations.

TABLE 27. THE NUMBER OF TEMPERATURE RECORDS, FISH RECORDS, AND FISH-TEMPERATURE DATA SETS BY STATION, FOR LAKES AND RESERVOIRS

Station*	Number of records		Number of fish-temperature data sets	Station*	Number of records		Number of fish-temperature data sets
	Temperature	Fish			Temperature	Fish	
10000†	0	0	0	70600	90	143	2
10100	11	132	2	70700	109	115	1
10101	33	463	2	70800	41	161	1
10102	23	264	2	80200†	0	0	0
20000†	0	0	0	110000†	0	0	0
20600	13	17	1	110300	5	416	3
21300	8	3	0	110400	12	93	2
21400	4	2	0	110500	4	90	0
21700	19	74	2	110600	23	337	3
22800	2	3	1	110700	13	205	2
22900	4	23	1	110800	26	88	4
23000	32	102	1	110900	11	126	4
30100	48	115	3	111000	21	259	5
30101	137	245	3	111100	2	32	0
30300	290	148	5	111200	1	0	0
30400	91	390	7	111300	0	15	0
30500	77	36	3	111400†	0	0	0
40100†	0	0	0	111500†	0	0	0
40300	98	181	4	150000†	0	0	0
40400	14	124	1	150100	37	69	1
40401	8	50	1	150200	0	215	0
40500	18	113	1	150300	148	716	3
41000†	0	0	0	150700	25	2314	4
50500	4	167	1	150800†	0	0	0
50900	12	61	1	160000†	0	0	0
51300	114	272	5	160100	313	242	14
51900†	0	0	0	160200	363	224	6
52000	0	121	0	160300	34	82	3
52300†	0	0	0	160400	31	185	3
70100	48	12	1	160500	60	130	3
70300	455	75	2	160600	198	119	5
70400	150	95	2	160700	132	129	7
70500	58	149	1	160800	475	97	9

(continued)

TABLE 27. (continued)

Station*	Number of records		Number of fish-temperature data sets	Station*	Number of records		Number of fish-temperature data sets
	Temperature	Fish			Temperature	Fish	
160900	52	255	3	250200†	0	0	0
161100†	0	0	0	250300†	0	0	0
180100†	0	0	0	250400†	0	0	0
190000†	0	0	0	250600	2	43	1
190100	28	14	2	250700	1	34	1
190200	10	9	1	260300	39	569	4
190300	37	18	1	260400†	0	0	0
190400	10	11	1	270100	673	29	1
190500	4	15	1	270200	191	20	1
190600	12	28	1	270500	563	358	6
190700	12	7	1	290000	0	0	0
190800	4	5	1	290100†	102	28	2
190900	2	42	1	290300†	0	0	0
191000	181	23	2	290400	30	36	1
191100	6	6	1	290500†	0	0	0
191400	16	9	2	290600†	0	0	0
191500	8	5	1	300200	1	8	1
191600	5	40	3	310400	56	103	1
200100	31	151	1	310500	306	278	1
200200	38	120	1	310600	0	409	0
210300	16	803	0	310601	37	0	0
210400	16	0	0	310602	52	103	0
210700	6	15	1	310603	50	0	0
210900	8	64	2	310604	41	3	1
211000	26	62	2	310605	39	100	1
211100	32	30	1	310606	34	67	2
211200	43	45	0	310607	0	34	0
220100	133	12	1	310800	0	142	0
220300	8	3	0	310900	358	211	2
230200	27	28	1	311000	40	114	3
230300	21	28	1	311101	0	98	0
230400	5	38	1	311102	0	274	0
250000†	0	0	0	311103	75	236	0
(continued)							

TABLE 27. (continued)

Station*	Number of records		Number of fish-temperature data sets	Station*	Number of records		Number of fish-temperature data sets
	Temperature	Fish			Temperature	Fish	
311104	0	192	0	390500	2	23	2
311200	32	246	1	390600	31	67	4
320200	4	9	1	400600	153	10	4
340200	77	389	4	400800	8373	240	11
350000†	0	0	0	401300†	0	0	0
350100†	0	0	0	430100†	0	0	0
350400	5	35	4	460000†	0	0	0
350800†	0	0	0	460100	98	433	4
350900	6	79	4	460200†	0	0	0
351000	5	38	4	470000†	0	0	0
351100	2	16	1	470100†	0	0	0
351200	3	28	2	470900†	0	0	0
360100†	0	0	0	471000†	0	0	0
360300	20	31	1	480000†	0	0	0
360400	3	40	1	480100	234	689	2
360500	3	37	1	480101	197	586	2
360600	3	21	1	480200	117	595	5
360700	52	109	1	480300	18	557	3
360800	589	41	5	480400	34	89	1
360900	442	45	4	480500	32	121	2
361100	398	16	1	480600	48	177	1
361200	0	162	0	480700	14	285	3
361500	9	43	1	481000†	0	0	0
361600	8	35	1	481100	68	295	3
361700	7	38	1	481200	42	477	1
361800	8	45	1	481300	972	48	1
361900	8	20	0	481400	191	456	2
362000	10	21	1	481500	137	317	2
380100†	0	0	0	481600	69	185	0
390000†	0	0	0	481700	160	736	1
390100	178	121	5	481800	12	39	1
390300	96	1122	5	481900	16	536	2
390400	195	146	1	482000†	0	0	0

(continues)

TABLE 27. (continued)

Station*	Number of records		Number of fish-temperature data sets	Station*	Number of records		Number of fish-temperature data sets
	Temperature	Fish			Temperature	Fish	
482100	165	117	0	551400	5	16	1
490000†	0	0	0	551500	52	9	1
490200	107	204	4	560000†	0	0	0
490300	19	302	2	560200	223	375	18
490400	112	118	3	560400	0	5	0
490401	108	0	0	560500	0	5	0
500100	25	467	12	560700	0	5	0
540200	166	2	2	560900	754	236	7
540300	201	10	3	561000	77	343	15
540400	145	4	2	561200	468	505	15
550100	36	111	3	561300	4	24	1
550200	31	62	2	561500†	0	0	0
550400	40	32	0	561600†	0	0	0
550500	43	24	1	561700†	0	0	0
550600	91	30	4	561800†	0	0	0
550700	43	66	3	561900†	0	0	0
550800	32	50	3	570000†	0	0	0
550900	34	42	2	570300	2	99	2
551000	3	23	1	570600†	0	0	0
551100	11	8	0				
551200	28	18	1				
551300	6	4	0				

*Station locations are given in Appendix C.

†Spawning information only is available at these stations.

composition and abundance at a particular station (say station number 20900, which is Bear Creek on the Kenai Peninsula in Alaska where there are 3326 fish records). Other uses might include checking fish or temperature records at a given station or stations independently before and after a major industry, dam, power plant, etc. was constructed.

The number of fish-temperature data sets in the data base for each fish species in both the lake-reservoir and stream-river categories are given in Table 28. This table may be used for deciding whether an analyses of the temperature requirements for a given species as deduced from its presence in natural waters where temperature information is available might be worthwhile. For this two examples will suffice. First let us consider an analyses for rainbow smelt (*Osmerus mordox*). From Table 28 we find there are no lake-reservoir data sets and only one stream-river data set and thus insufficient data for an analyses. Second let us consider an analyses for channel catfish (*Ictalurus punctatus*). On checking Table 28 we find that there are 151 and 174 fish-temperature data sets for the lake-reservoir and stream-river categories, respectively and thus sufficient data for further analyses.

Fish census methods used for the 50 species of freshwater fish encoded in the stream-river category where there were matching fish-temperature data sets are given in Table 29. This data indicates methods most frequently used. One might conclude that the "combination method" was the most effective, however, this says nothing. Although, it does suggest that all fish censussing should state which method(s) was(were) used and how many fish were counted by each. Useful conclusions about effective method of censussing for all 50 species might be that "creel", "electro", "seining", and "fish ladders" were the most effective.

TABLE 28. THE NUMBER OF FISH-TEMPERATURE DATA SETS IN THE DATA BASE FOR EACH FISH SPECIES

Species	Number of fish-temperature data sets	
	Lake-Reservoir	Stream-River
Petromyzontidae-lampreys		
Chestnut lamprey (318)	0	3
Pacific lamprey (59)	0	76
Sea lamprey (354)	0	1
Silver lamprey (175)	0	3
Southern brook lamprey (326)	0	2
Acipenseridae-sturgeons		
Atlantic sturgeon (220)	0	1
Green sturgeon (70)	0	0
Lake sturgeon (116)	13	10
Pallid sturgeon (320)	3	0
Shovelnose sturgeon (113)	3	48
White sturgeon (1)	0	38
Polyodontidae-paddlefishes		
Paddlefish (190)	7	137
Lepisosteidae-gars		
Alligator gar (272)	9	10
Florida gar (245)	2	0
Longnose gar (121)	49	49
Shortnose gar (161)	28	26
Spotted gar (134)	35	20
Amiidae-bowfins		
Bowfin (119)	33	136
Elopidae-tarpons		
Ladyfish (285)	0	3
Tarpon (251)	0	0
Anguillidae-freshwater eels		
American eel (143)	7	138
Clupeidae-herrings		
Alabama shad (234)	0	0
Alewife (2)	10	9
American shad (60)	1	96
Blueback herring (150)	1	5
Gizzard shad (3)	92	69
Hickory shad (298)	0	3
Skipjack herring (186)	6	23
Threadfin shad (4)	47	28

(continued)

TABLE 28. (continued)

Species	Number of fish-temperature data sets	
	Lake-Reservoir	Stream-River
Hiodontidae-mooneyes		
Goldeye (164)*	8	26
Mooneye (118)	17	47
Salmonidae-trouts		
Artic char (314)	2	0
Artic grayling (105)	0	5
Atlantic salmon (14)	1	11
Brook trout (16)	16	69
Brown trout (15)	23	64
Chinook salmon (10)	10	208
Chum salmon (7)	0	94
Coho salmon (8)	6	176
Cutthroat trout (12)	24	43
Dolly Varden (92)	7	57
Golden trout (200)	1	0
Kokanee salmon (45)	19	5
Lake herring (114 and 193)	0	0
Lake trout (17)	18	0
Lake whitefish (5)	0	0
Mountain whitefish (11)	23	109
Pink salmon (6)	0	102
Rainbow trout (13)	86	172
Round whitefish (196)	0	0
Sockeye salmon (9)	0	104
Steelhead trout (46)	0	185
Engraulidae-anchovies		
Bay anchovy (142)	0	6
Osmeridae-smelts		
Eulachon (89)	1	0
Rainbow smelt (18)	0	1
Umbridae-mudminnows		
Alaska blackfish (315)	0	2
Central mudminnow (323)	0	0
Esocidae-pikes		
Chain pickerel (19)	16	58
Grass pickerel (131)	6	10
Muskellunge (21)	20	3
Northern pike (20)	61	45
Redfin pickerel (203)	3	3

(continued)

TABLE 28. (continued)

Species	Number of fish-temperature data sets	
	Lake-Reservoir	Stream-River
Characidae-characins		
Mexican tetra (276)*	1	1
Cyrinidae-minnows and carps		
Arkansas River shiner (269)	1	0
Bigeye chub (214)	0	4
Bigeye shiner (345)	0	2
Bigmouth shiner (139)	1	7
Blackchin shiner (357)	0	0
Blacknose dace (67)	0	29
Blacknose shiner (356)	0	0
Blackspot shiner (302)	1	0
Blacktail shiner (207)	5	14
Bleeding shiner (229)	0	1
Bluehead chub (219)	0	1
Bluestripe shiner (242)	0	0
Bluntnose minnow (128)	7	18
Bluntnose shiner (263)	0	0
Bonytail (47)	8	11
Bridle shiner (337)	0	1
Bullhead minnow (210)	13	9
Carp (22)	134	356
Chiselmouth (68)	4	0
Coastal shiner (311)	0	0
Colorado squawfish (49)	1	7
Comely shiner (353)	0	17
Common shiner (183)	0	53
Creek chub (57)	4	38
Cutlips minnow (338)	0	27
Cypress minnow (319)	0	0
Emerald shiner (115)	6	10
Fallfish (195)	1	48
Fathead minnow (23)	7	10
Finescale dace (309)	0	1
Flathead chub (266)	2	6
Ghost shiner (359)	0	5
Golden shiner (91)	78	44
Goldfish (79)	9	5
Hitch (99)	0	0
Hornyhead chub (182)	0	8
Humpback chub (48)	0	2
Lahontan redside (88)	0	9
Longnose dace (95)	2	28
Longnose shiner (218)	1	1
Mimic shiner (293)	3	6

(continued)

TABLE 28. (continued)

Species	Number of fish-temperature data sets	
	Lake-Reservoir	Stream-River
Cyprinidae-minnows and carps (continued)		
Northern squawfish (63)*	4	70
Oregon chub (62)	0	0
Ozark minnow (227)	0	1
Pallid shiner (307)	0	2
Peamouth (69)	0	0
Plains minnow (254)	5	0
Proserpine shiner (282)	3	0
Pugnose minnow (215 and 274)	6	4
Redeye chub (208)	0	1
Redfin shiner (125 and 305)	2	3
Red shiner (100)	29	12
Redside shiner (56)	3	72
Ribbon shiner (301)	3	2
Rio Grande shiner (281)	1	0
River chub (346)	0	1
River shiner (267)	2	2
Rosefin shiner (351)	1	3
Rosyface shiner (348)	0	6
Sabine shiner (327)	0	9
Sacramento squawfish (107)	0	0
Sand shiner (185)	8	7
Satinfin shiner (262)	1	24
Sharpsone shiner (291)	2	0
Silverband shiner (322)	2	0
Silver chub (174)	0	8
Silverjaw minnow (347)	0	0
Silver shiner (344)	0	1
Silvery minnow (206)	5	5
Speckled chub (265)	4	5
Speckled dace (50)	0	17
Spotfin shiner (184)	0	8
Spottail shiner (157)	5	35
Steelcolor shiner (340)	0	0
Stoneroller (158)	4	20
Striped shiner (136)	0	0
Sturgeon chub (321)	1	0
Suckermouth minnow (268)	3	3
Swallowtail shiner (336)	0	19
Taillight shiner (243)	8	0
Tamaulipas shiner (283)	5	0
Tench (61)	1	18
Texas shiner (280)	2	0
Tui chub (80)	6	0
Utah chub (55)	6	3

(continued)

TABLE 28. (continued)

Species	Number of fish-temperature data sets	
	Lake-Reservoir	Stream-River
Cyprinidae-minnows and carps (continued)		
Weed shiner (241)*	0	8
Whitetail shiner (228)	0	1
Catostomidae-suckers		
Bigmouth buffalo (27)	16	25
Black buffalo (255)	4	20
Black redhorse (192)	1	6
Blacktail redhorse (204)	2	10
Bluehead sucker (52)	3	8
Blue sucker (223)	5	13
Bridgelip sucker (66)	2	0
Creek chubsucker (197)	0	11
Cui-ui (111)	1	0
Flannelmouth sucker (51)	10	12
Golden redhorse (138)	11	22
Gray redhorse (294)	7	1
Greater redhorse (163)	0	1
Highfin carpsucker (168)	1	2
Humpback sucker (53)	0	5
Lake chubsucker (132)	12	0
Largescale sucker (94)	4	0
Longnose sucker (24)	3	6
Mountain sucker (85)	0	2
Northern hog sucker (191)	4	17
Quillback (123)	18	67
River carpsucker (133)	40	39
River redhorse (169)	3	10
Smallmouth buffalo (26)	43	43
Sharpfin chubsucker (212)	0	1
Shorthead redhorse (170)	7	32
Silver redhorse (165)	1	19
Spotted sucker (162)	18	36
Suckermouth redhorse (258)	1	0
Tahoe sucker (83)	3	0
Utah sucker (101)	0	1
White sucker (25)	40	96
Ictaluridae-freshwater catfishes		
Black bullhead (28)	72	41
Black madtom (328)	0	1
Blue catfish (187)	26	47
Brindled madtom (209)	0	2
Brown bullhead (30)	55	55
Carolina madtom (339)	0	0

(continued)

TABLE 28. (continued)

Species	Number of fish-temperature data sets	
	Lake-Reservoir	Stream-River
Ictaluridae-freshwater catfishes (continued)		
Channel catfish (31)*	151	174
Flat bullhead (233)	0	1
Flathead catfish (109 and 256)	53	85
Freckled madtom (329)	0	6
Margined madtom (290)	0	17
Slender madtom (232)	0	0
Speckled madtom (205)	0	3
Stonecat (271)	3	3
Tadpole madtom (137)	5	3
White catfish (82)	19	14
Yellow bullhead (29)	62	36
Ariidae-sea catfishes		
Sea catfish (317)	0	2
Aphredoderidae-pirate perches		
Pirate perch (201)	6	13
Percopsidae-trout-perch		
Trout-perch (65)	0	5
Gadidae-codfishes		
Burbot (84)	22	17
Belonidae-needlefishes		
Atlantic needlefish (151)	0	6
Cyprinodontidae-killifishes		
Banded killifish (153)	1	18
Blackspotted topminnow (217)	0	9
Blackstripe topminnow (140)	5	9
Bluefin killifish (250)	2	0
Desert pupfish (106)	0	0
Golden topminnow (306)	1	1
Mummichog (154)	0	4
Northern studfish (231)	0	0
Plains killifish (264)	3	1
Rainwater killifish (156)	0	4
Seminole killifish (247)	7	0
Sheepshead minnow (155)	7	4
Starhead topminnow (129)	1	1
Poeciliidae-livebearers		
Amazon molly (278)	0	1

(continued)

TABLE 28. (continued)

Species	Number of fish-temperature data sets	
	Lake-Reservoir	Stream-River
Poeciliidae-livebearers (continued)		
Sailfin molly (275)*	3	1
Mosquitofish (90)	23	9
Atherinidae-silversides		
Brook silverside (130)	17	8
Mississippi silverside (270)	0	0
Tidewater silverside (152)	13	5
Gasterosteidae-sticklebacks		
Brook stickleback (120)	1	0
Fourspine stickleback (146)	0	3
Ninespine stickleback (324)	0	0
Threespine stickleback (64)	0	12
Percichthyidae-temperate basses		
Striped bass (33)	5	24
White bass (32)	58	87
White perch (144)	4	15
Centrarchidae-sunfishes		
Banded pygmy sunfish (180)	1	4
Banded sunfish (295)	1	0
Blackbanded sunfish (288)	1	1
Black crappie (39)	139	84
Bluegill (35)	240	162
Bluespotted sunfish (248)	3	1
Dollar sunfish (246)	1	1
Flier (222)	6	4
Green sunfish (34)	102	76
Guadalupe bass (297)	2	1
Largemouth bass (37)	264	134
Longear sunfish (188)	53	82
Mud sunfish (289)	0	3
Orangespotted sunfish (122)	21	12
Pumpkinseed (117)	52	41
Redbreast sunfish (194)	22	43
Redear sunfish (103)	94	24
Redeye bass (239)	0	1
Roanoke bass (284)	0	0
Rock bass (126)	39	100
Sacramento perch (81)	2	1
Smallmouth bass (36)	35	138
Spotted bass (189)	30	61
Spotted sunfish (127)	16	14

(continued)

TABLE 28. (continued)

Species	Number of fish-temperature data sets	
	Lake-Reservoir	Stream-River
Centrarchidae-sunfishes (continued)		
Warmouth (108)*	79	56
White crappie (38)	125	73
Percidae-perches		
Banded darter (342)	0	0
Blackbanded darter (240)	0	0
Blackside darter (332)	0	2
Bluntnose darter (330)	0	4
Channel darter (349)	0	0
Cypress darter (331)	0	2
Dusky darter (333)	0	5
Fantail darter (312)	0	1
Fountain darter (286)	0	1
Greenside darter (343)	0	6
Greenthroat darter (300)	1	0
Harlequin darter (360)	0	0
Iowa darter (171)	0	0
Johnny darter (181)	1	25
Logperch (173)	9	16
Naked sand darter (216)	0	0
Orangethroat darter (230)	0	2
Rainbow darter (341)	0	1
River darter (172)	0	2
Sauger (41)	20	54
Scaly sand darter (303)	1	9
Shield darter (352)	0	18
Slenderhead darter (350)	0	0
Slough darter (304)	1	2
Swamp darter (198)	0	1
Walleye (42)	76	91
Western sand darter (361)	0	2
Yellow perch (40)	52	58
Sparidae-porgies		
Pinfish (287)	0	2
Sheepshead (358)	0	48
Sciaenidae-drums		
Atlantic croaker (211)	0	2
Freshwater drum (43)	73	184
Red drum (299)	0	1
Silver perch (149)	0	2
Spot (148)	0	4

(continued)

TABLE 28. (continued)

Species	Number of fish-temperature data sets	
	Lake-Reservoir	Stream-River
Cichlidae-cichlids		
Blackchin mouthbrooder (252)*	3	4
Rio Grande perch (273)	15	1
Mugilidae-mullets		
Mountain mullet (237)	0	0
Striped mullet (104)	7	24
Gobiidae-gobies		
Naked goby (147)	0	4
Cottidae-sculpins		
Banded sculpin (226)	0	7
Mottled sculpin (54)	0	6
Piute sculpin (98)	0	9
Bothidae-lefteye flounders		
Southern flounder (213)	0	5
Soleidae-soles		
Hogchoker (145)	0	7

* Species code numbers in the data base. Scientific name is given in Appendix A.

TABLE 29. FISH CENSUS METHODS USED FOR 50 SPECIES OF FRESHWATER FISH ENCODED IN THE STREAM-RIVER CATEGORY

Species	Electro-fishing	Gill net	Weir	Creel	Poison	Ladder	Seine	Trap	Stream diversion	Trap net	Trawl	Fyke net	Combin-ation	Hoop net	Trammel net	Trot line
White sturgeon	-	-	3	-	-	35	-	-	-	-	-	-	-	-	-	-
Alewife	1	-	-	1	2	-	1	-	-	-	6	-	2	-	-	-
Gizzard shad	14	5	10	-	17	-	11	-	-	-	-	-	23	1	-	-
Threadfin shad	1	8	-	-	3	-	5	-	-	-	4	-	22	-	-	-
Lake whitefish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pink salmon	3	-	38	1	-	35	-	-	-	-	-	-	25	-	-	1
Chum salmon	2	-	36	-	-	41	-	-	-	-	-	-	10	-	-	-
Coho salmon	2	3	70	3	-	79	1	1	1	-	-	1	-	-	-	2
Sockeye salmon	-	2	22	-	-	72	-	-	-	-	-	1	-	-	-	8
Chinook salmon	8	-	41	6	-	102	-	4	-	-	-	4	-	-	-	-
Mountain whitefish	3	2	-	2	-	69	1	-	9	-	-	-	-	-	-	2
Cuttroat trout	-	-	3	2	-	1	-	-	-	-	-	-	-	-	-	-
Rainbow trout	32	18	34	43	-	7	2	8	9	-	-	1	-	-	-	3
Atlantic salmon	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brown trout	24	10	15	8	-	1	-	-	9	-	-	-	2	-	-	2
Brook trout	40	9	7	26	-	-	-	8	9	-	-	-	-	-	-	-
Lake trout	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rainbow smelt	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Chain pickerel	39	-	-	5	17	-	-	2	-	-	-	-	5	-	-	2
Northern pike	12	2	8	38	-	2	4	-	-	4	-	-	3	-	-	-
Muskellunge	4	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
Carp	40	17	10	62	9	69	17	2	-	2	6	-	220	12	2	19
Fathead minnow	1	4	-	-	-	-	8	-	-	-	-	-	1	-	-	5
Longnose sucker	-	-	10	-	-	-	-	-	-	-	-	-	2	-	-	-
White sucker	91	10	10	6	4	-	13	3	-	4	2	-	2	4	-	5
Smallmouth buffalo	9	3	-	-	11	-	4	-	-	2	2	-	23	7	-	-
Bigmouth buffalo	10	-	-	-	4	-	-	-	-	4	-	-	20	-	-	-
Black bullhead	5	4	6	2	2	-	7	1	-	2	4	-	12	4	-	4
Yellow bullhead	14	-	-	10	2	-	1	2	-	4	-	-	13	-	-	2
Brown bullhead	36	-	-	10	6	-	1	4	-	4	-	-	13	1	-	2
Channel catfish	21	17	8	45	21	39	11	4	-	2	4	-	24	9	-	6
White bass	11	10	10	57	3	-	4	-	-	2	-	-	21	-	-	-
Striped bass	-	-	1	8	-	2	12	-	-	-	6	-	-	-	-	4
Green sunfish	23	1	-	26	15	3	7	4	-	2	-	-	1	3	-	1
Smallmouth bass	53	2	-	53	5	-	24	2	-	4	2	-	4	-	-	9
Largemouth bass	33	1	4	53	21	-	5	3	-	4	2	-	25	5	-	2
White crappie	12	11	6	17	13	-	6	2	-	2	4	-	21	8	-	-
Black crappie	27	7	2	23	11	-	1	5	-	4	4	-	24	3	-	2
Yellow perch	34	6	-	24	-	-	8	2	-	2	2	-	4	-	-	2
Sauger	8	8	-	35	3	-	6	-	-	2	6	-	19	4	-	-
Walleye	26	9	8	54	7	1	13	-	-	2	4	-	4	4	-	1
Freshwater drum	8	11	-	34	10	-	9	-	-	-	8	-	171	4	-	-
Mosquitofish	-	-	-	-	-	-	7	-	-	-	-	-	2	-	-	-
Golden shiner	28	-	-	2	-	5	5	2	-	-	-	-	13	1	-	-
Redear sunfish	5	-	-	1	8	-	1	-	-	-	-	-	4	2	-	-
Flathead catfish	8	1	-	38	20	-	1	1	-	2	2	-	21	2	-	1
Shovelnose sturgeon	-	-	-	3	-	-	-	-	-	-	-	-	55	2	-	-
Lake herring	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Emerald shiner	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-
Bluegill	33	1	-	78	24	-	9	4	-	4	6	-	27	-	-	2
All species	743	182	359	776	238	564	235	64	37	60	74	7	836	76	2	177

SECTION 6

CASE EXAMPLE STUDIES

FISH POPULATION AND WATER TEMPERATURE CHANGES

Changes in river water temperature following dam construction along with information about changes or stability of fish populations are noted and discussed in the first three examples in this section. The fourth example is of a creek with a relatively stable temperature but yet changes in fish population dynamics.

Columbia River

The observed monthly mean temperatures on the Columbia River below the Bonneville Dam for the period from 1948 to 1968 are given in Figure 11. Also included in this figure are the completion dates for upstream dams and the number of nuclear reactors in operation at the AEC Hanford reservation located near Richland, Washington. An overall rise in river temperatures is apparent in Figure 11. This agrees with the results of a detailed analysis of the Columbia River thermal regime performed by Moore (1968). He showed that a major upward shift in river temperatures occurred after 1956. The rise in temperature ranged from 0.5 F (0.3 C) in September to about 2 F (1.1 C) in winter. Moore (1968) concluded that the rise in Columbia River temperatures was caused by heated discharges from the Hanford reactors. However, the intentional release of cooler water from Lake Roosevelt and Brownlee Reservoirs to offset the heating effects of the Hanford operation, warmed the Bonneville temperature regime in fall and winter and cooled it in spring and summer. This explains why the overall temperature increase was only about 1 F (0.6 C) in summer and 2 F (1.1 C) in fall and winter. Construction of reservoirs above the Dalles and McNary Dams is believed to have played a minor role in the overall rise in Columbia River temperatures.

Total annual fish counts from Bonneville Dam for American shad (Alosa spidissima), northern squawfish (Ptychocheilus oregonensis), and coho (Oncorhynchus kisutch) and chinook salmon (Oncorhynchus tshawytscha) are shown in Figures 12, 13, and 14. A major change in total annual counts for all four species occurred between 1960 and 1962. The shad and coho salmon increased, while the squawfish and chinook salmon both decreased. However, these changes are difficult to evaluate because of the many factors involved. Specifically, it is known that irrigation, logging, mining, dam construction and other activities by man seriously reduce both the size and capacity of chinook salmon spawning areas in the Northwest (Fulton 1968). Additionally, a major hatchery program for chinook and coho salmon

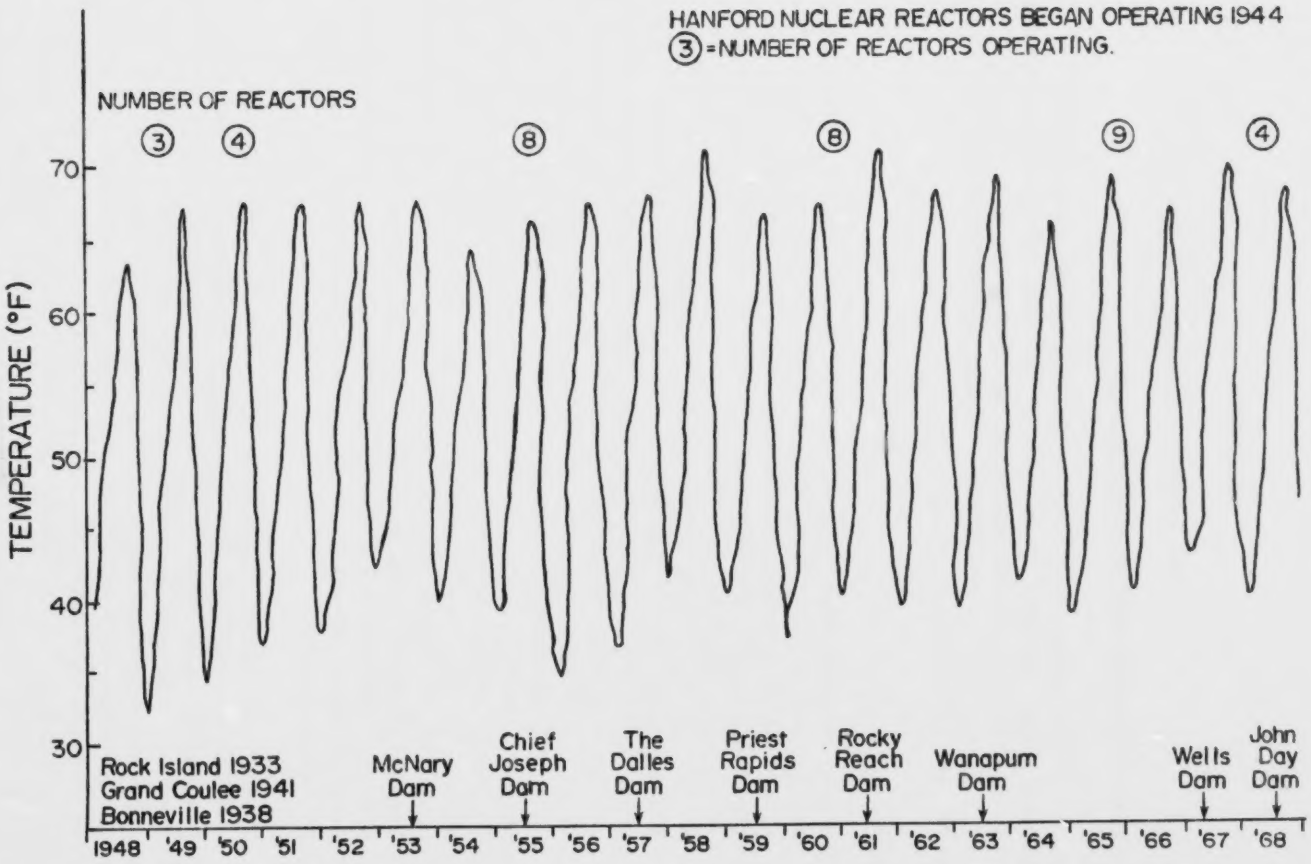

Figure 11. Historical monthly mean temperatures of Columbia River at Bonneville Dam.

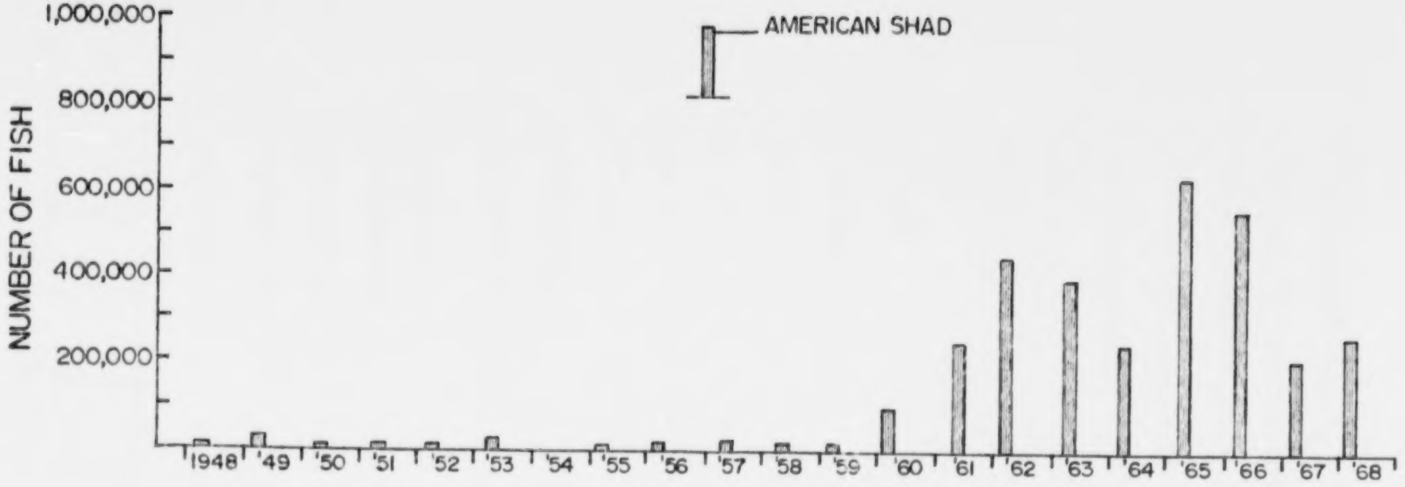

Figure 12. Yearly fish count of american shad over Bonneville Dam.

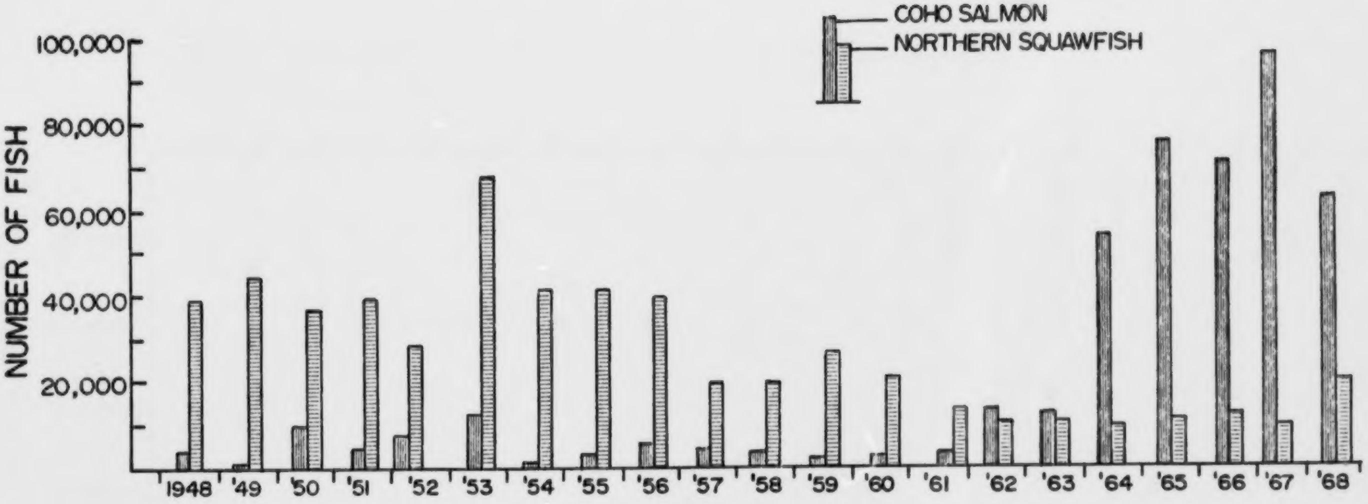

Figure 13. Yearly fish count of coho salmon and northern squawfish over Bonneville Dam.

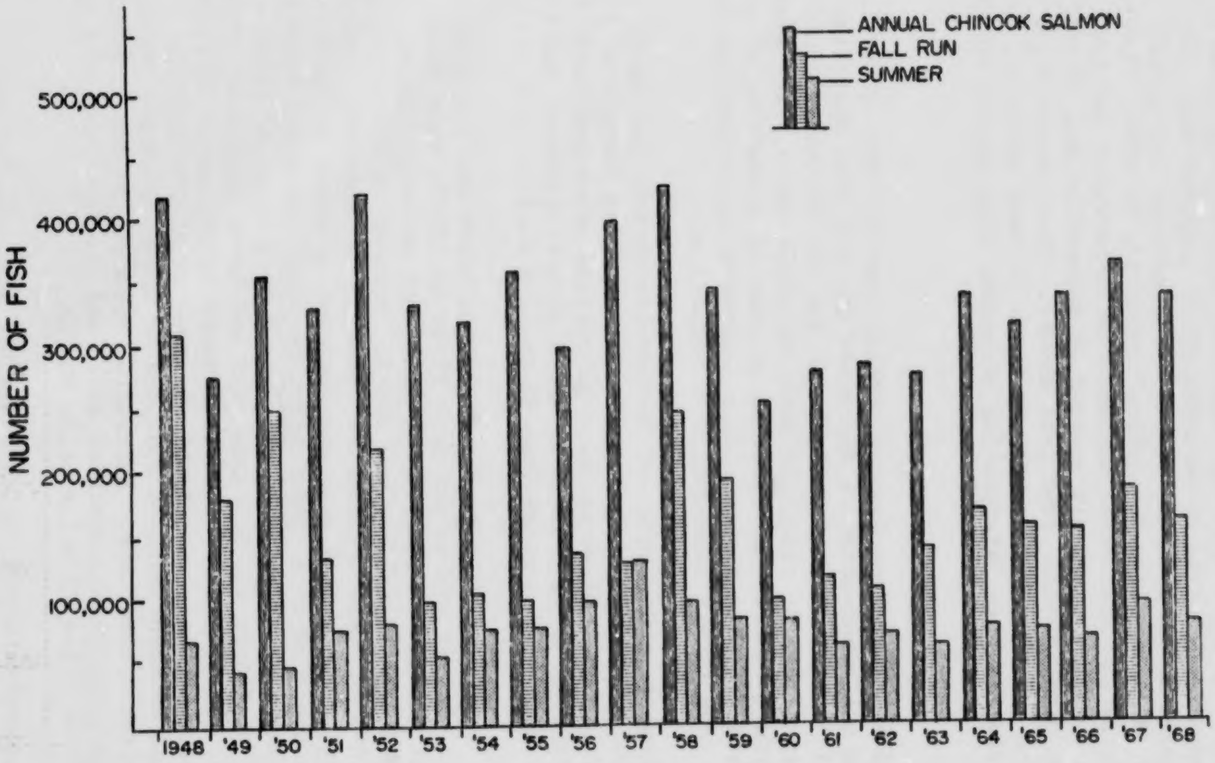

Figure 14. Yearly fish count of chinook salmon over Bonneville Dam.

on the Columbia River was instituted in the mid 50's (Glenn A. Flittner, personal communication). Also, an eradication program for squawfish was conducted in 1957 in the Columbia River as a result of their predation on juvenile hatchery salmon (LaRivers 1962). Thus, only the change in shad populations can be discussed with any degree of certainty in terms of the effects of the man-induced rise in Columbia River temperatures. In this case, there appeared to be a direct relationship between the overall warmer temperatures and the population "explosion" occurring in 1960. However, it should be pointed out that other unidentified warm-water species, including carp and suckers that are routinely counted at Bonneville Dam, showed a marked decline in numbers after 1960 (not shown). Thus, where major man-made alterations to the natural environment are known to have occurred, considerable caution must be exercised in interpreting attendant fish population changes.

Green River

The Green River flows from Wyoming through Utah and into Colorado. Flaming Gorge Dam was constructed on the river and put into operation in the fall of 1962. This is a relatively large dam and discharges cold water from the lower depths of the reservoir into the river below. The general effect of this type of stream modification is seen in a lowering of average annual temperatures but with higher winter temperatures, a decrease in turbidity, and a reduction in seasonal flow variation.

Figure 15 showing temperatures of the pre-impoundment and those observed afterwards just below the dam at Greendale is a striking example of the narrowed range of seasonal temperatures. An average pre-impoundment temperature range was from freezing to 72 F (22.2 C) while post-impoundment records at the same location indicated a range from 38 to 53 F (3.3 to 11.7 C).

The effects were noticeable on the fish population species composition. At Greendale, near the dam and as far down river as Little Hole where temperatures never reached 60 F (15.6 C), fish such as carp, channel catfish, and Colorado chub decreased or were not found. Vanicek et al. (1970) stated that no reproduction of these species was observed in 1964-1966. The redside shiner (Richardsonius balteatus) also was observed to occur in smaller numbers while the speckled dace (Rhinichthys osculus) increased markedly from 1964 to 1966. However, this could be attributed to a rotenone program prior to impoundment to eradicate all non-game fish and hence should be accepted with reservations. Rainbow trout were introduced in the upper stretches since the temperatures were more suitable to them after the damming. These species were termed abundant but not observed to spawn, probably because of the lack of suitable substrate. Successful spawning by the flannelmouth sucker (Catostomus latipinnis), speckled dace, and bluehead sucker (Catostomus discobolus) was first noted 23 miles below the dam.

At Jensen, approximately 90 miles below the dam, the temperature effects are far less apparent than upstream. Figure 16 shows the comparison of pre- and post-impoundment temperatures. The summer highs are reduced from about 73 to 66 F (22.8 to 18.9 C). Reproduction occurred for all native fish except the humpback sucker (Xyraucher texahus). The humpback sucker prefers

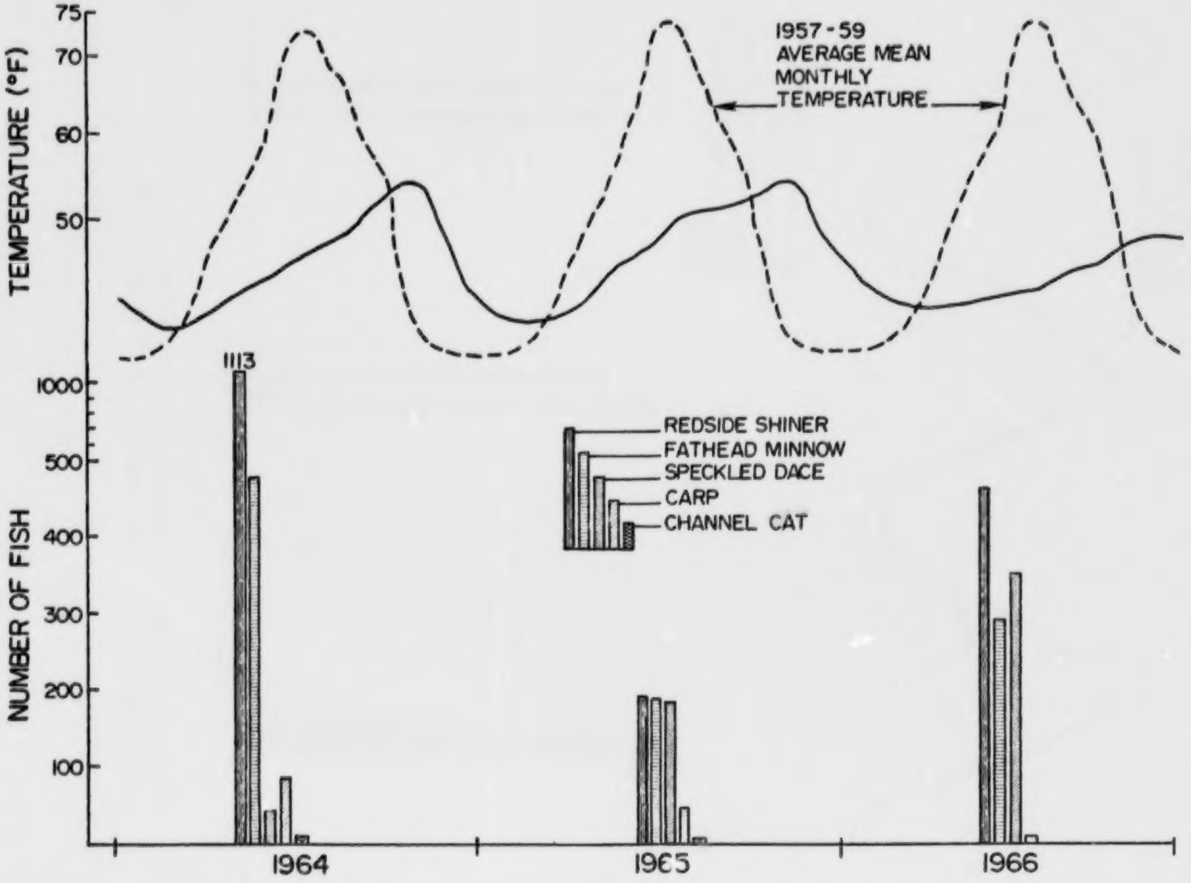

Figure 15. Historical average monthly temperatures for Green River near Greendale with the number of fish present.

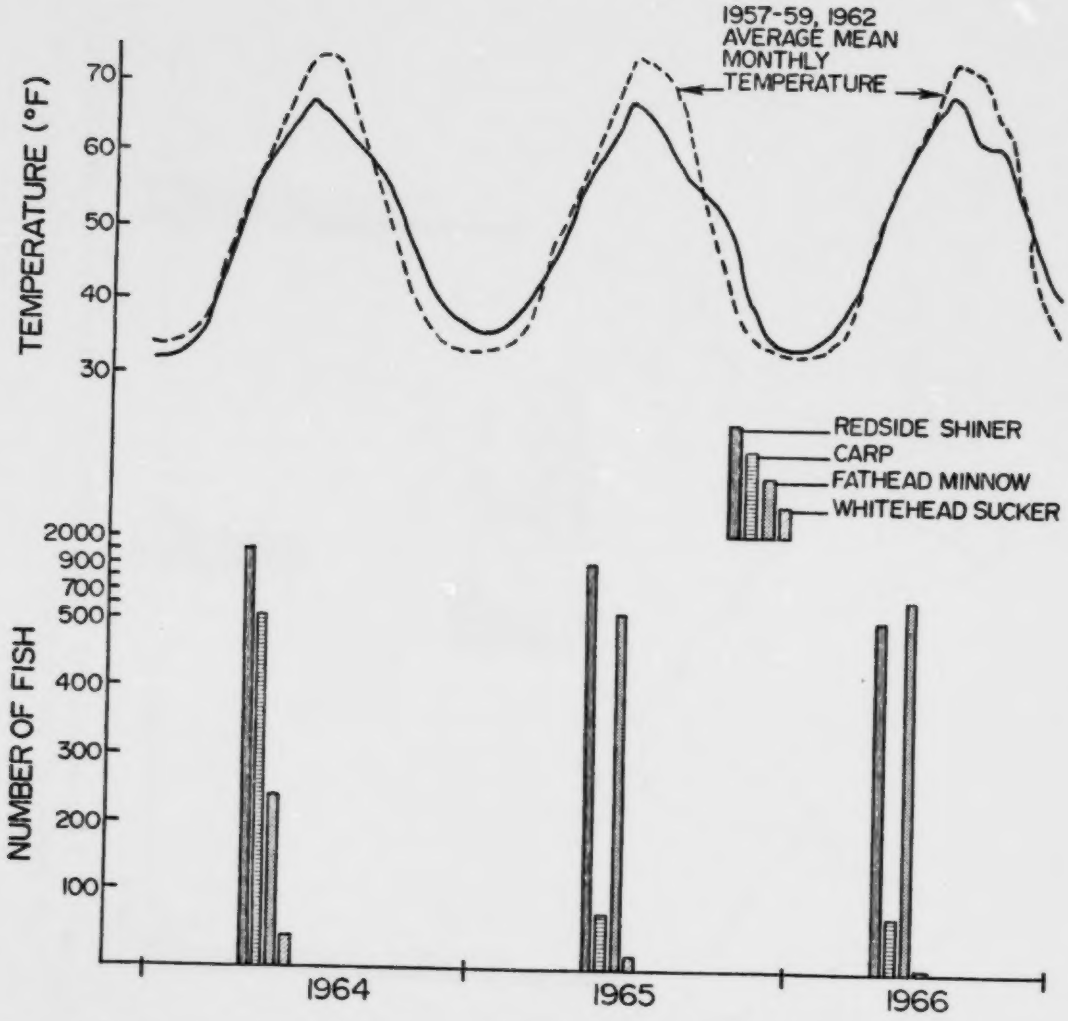

Figure 16. Historical average monthly temperatures for lower Green River near Jensen, with the number of fish present.

a torrential river habitat and has probably disappeared because of the lack of this habitat. The species composition shows, however, a sharp reduction in carp, a warmer-water fish, and disappearance of the whitehead sucker. While the temperature change was less drastic in the lower Green River, changes in the species composition and population numbers is probably in part the result of other factors such as lack of turbid water. However, the optimum temperature range for some of the native fish in the Green River appear to be slightly above that of the river. This, combined with other factors, possibly contributed to the observed declines in fish populations.

Trinity River

Temperature changes on the Trinity River in California occurred as a result of dam construction. Effects of dam construction noticeably decreased river water temperature as early as 1961. Upon completion of both Lewiston and Trinity Dams in 1963, maximum and mean water temperature decreased even further. There was a general increase in the minimum temperature during this period. These changes are evident in Figure 17 for which daily maximum and minimum temperatures were averaged by computer to plot monthly average maximum, minimum and mean temperatures.

The construction of Lewiston and Trinity Dams blocked the normal spawning runs of salmon and steelhead on the Trinity River from 1958 to 1960. While a hatchery was being built, fish were trapped and trucked from Lewiston to 11 miles above Trinity Dam. From 1960 to 1961 coho and chinook salmon were spawned at Lewiston or returned below in the river. Part of the steelhead run was transported above Trinity Dam in 1961. The permanent hatchery was opened in May 1963. Effects of the impoundment were observable during the summer of 1961 and afterwards by a lower range of temperature and a significant reduction to the summer highs previously observed. As shown in Figure 18, chinook salmon were the most abundant of the four species occurring in all but one of the ten years with a range of total number per year trapped from 9452 in 1962 to 3075 in 1965. Also shown on this figure are the average mean monthly temperatures for the Trinity River. It is difficult to see any direct correlation between the temperatures prevailing prior to the impoundment and the fish trapped and those resulting later when the temperatures were restricted to cooler summer waters. However, from 1962 to 1967 there was a decline in the number of chinook. Secondary impacts resulting from reduced flows are viewed as an important factor in this decline. Coho salmon numbers declined from 1962 to 1965 but the numbers returning in 1966 and 1967 exceeded the pre-impoundment population. The hatchery may have been wholly responsible for this fluctuation. Rainbow trout (Salmo gairdneri) continued through the ten-year-record at a steady level except for the last two years where data were missing or insufficient for analysis. Brown trout were random in occurrence and did not appear for a three-year period.

The four reported species generally prefer cold waters and were probably little affected by reducing the summer temperature highs. Changes in the relative abundance of warm water species may have occurred as was evident in

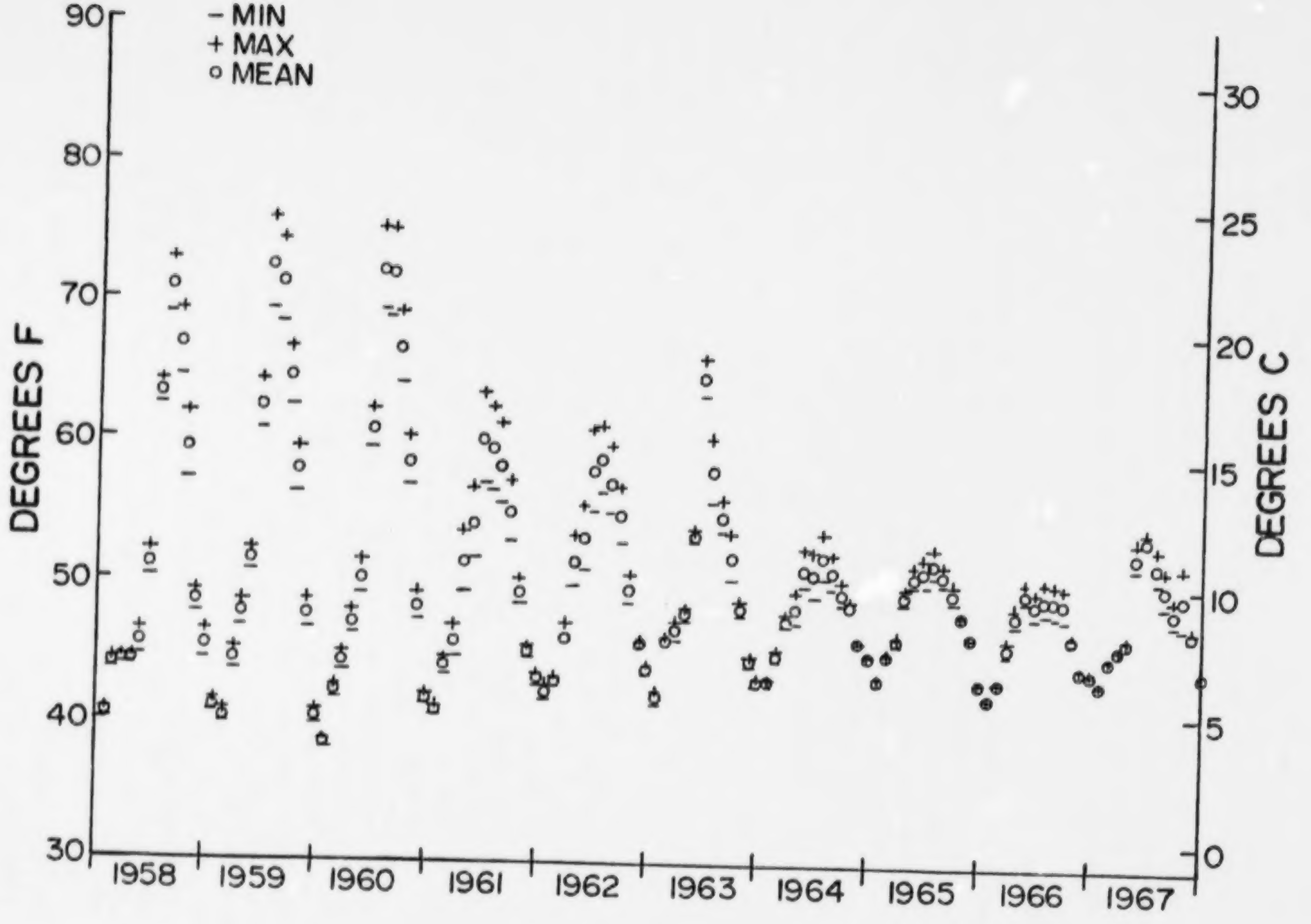

Figure 17. Average monthly temperatures at the Lewiston fish trapping facility.

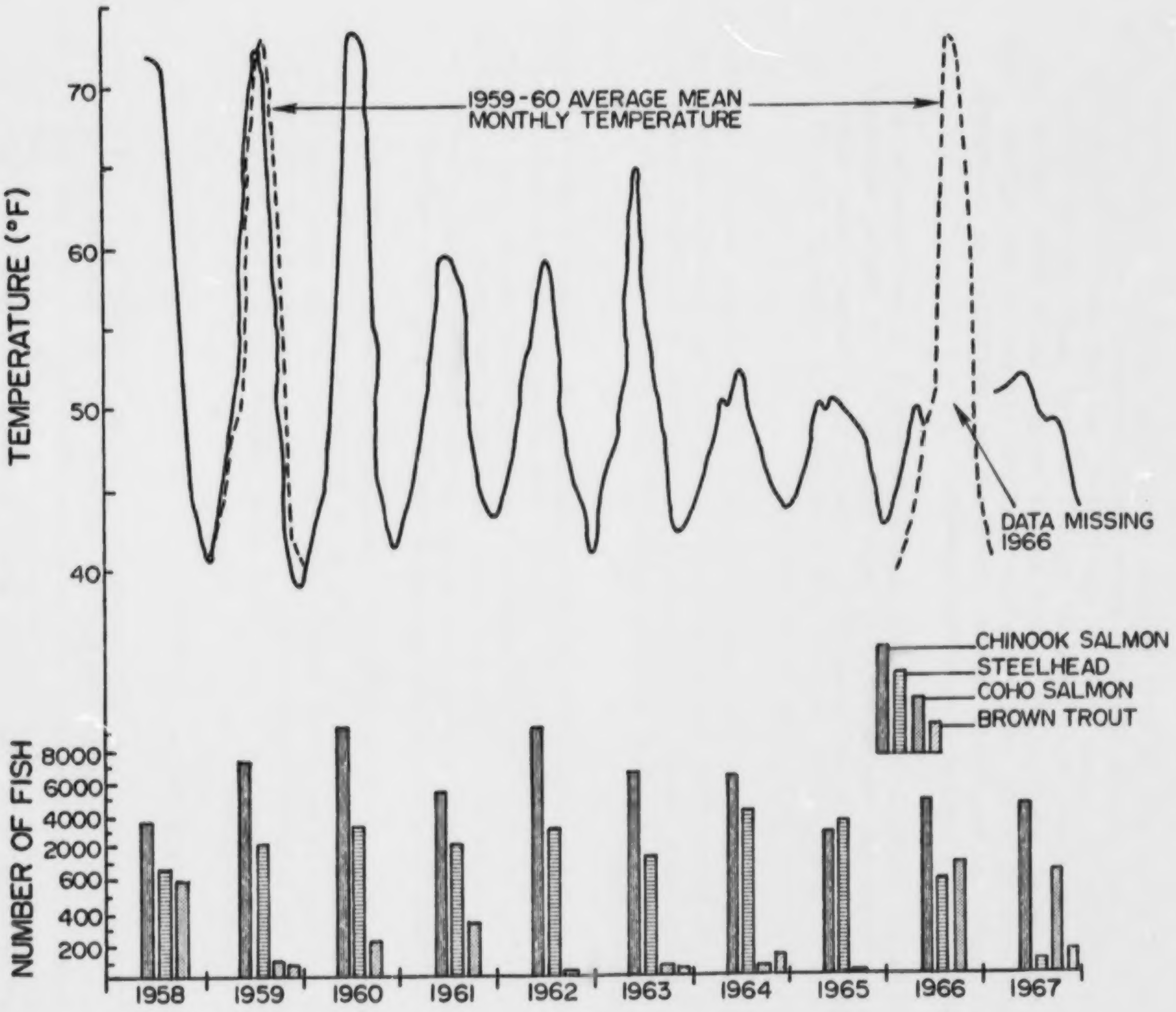

Figure 18. Historical mean monthly temperatures for the Trinity River at the Lewiston fish trapping facility.

the Green River following construction of the Flaming Gorge Dam but were not chronicled for the Trinity River.

Sagehen Creek

The observed mean monthly maximum temperature and total annual fish counts for brook trout, redside shiners, brown trout and suckers at Sagehen Creek are shown in Figure 19. Also shown is the 1953-61 average monthly temperature curve. Sagehen Creek is considered typical of many small streams on the eastern slope of the northern Sierra Nevada range. Aside from camping and fishing, grazing is the only important land use ajacent to the stream. Thus, for all practical purposes, Sagehen Creek can be considered as an example of a relatively pristine stream environment.

Climatic conditions at Sagehen Creek are severe as evidenced by mean monthly minimum air temperatures of less than 32 F (0 C) during September through June (Needham and Jones 1959). Annual water temperatures range from 32 F to 74 F (0 C to 23.3 C) with a maximum diel range of 22 F (5.5 C) occurring in July during periods of low flow.

In terms of the Sagehen fish populations a significant decline in numbers of brook and brown trout and an increase in suckers and shiners can be seen from the nine-year record in Figure 19. The numbers of sculpins, dace and whitefish (not shown) fluctuated irregularly during this period with no significant trends.

From the standpoint of temperature changes, the Sagehen Creek conditions appear to be relatively stable. However, the effect of the heaviest flood on record during December 1955 on Sagehen fish populations can be seen in 1956. Both fish populations and stream temperatures were the lowest of the nine-year period. Brook trout, shiners, and sucker populations recovered somewhat in 1957, however, brown trout did not occur again in significant numbers.

According to Gard and Flittner (unpublished manuscript 1978) the observed long-term decline in brook and brown trout cannot be ascribed to a temperature change or overfishing but is most likely the result of the 1955 flood which decimated the existing populations. The increase in suckers and shiners is most likely the result of a good year class spawned during the 1958-59 warm-water, low-flow years.

ANALYSIS OF A RIVER SYSTEM

The Mississippi River system was selected as an example of a river system that spans a wide range of temperature regimes from the headwaters to the mouth. This section provides a brief review of the selection process and the sequence of steps taken in collating and presenting the data to effect the analysis. A brief description of the present environment of the Mississippi River and an account of the historical changes in the river's environment due to man's activities are also presented. Hand plotted temperature regimes from selected stations on the Mississippi River and a discussion of these data is included. Basic consideration is given to the habitat preferences and

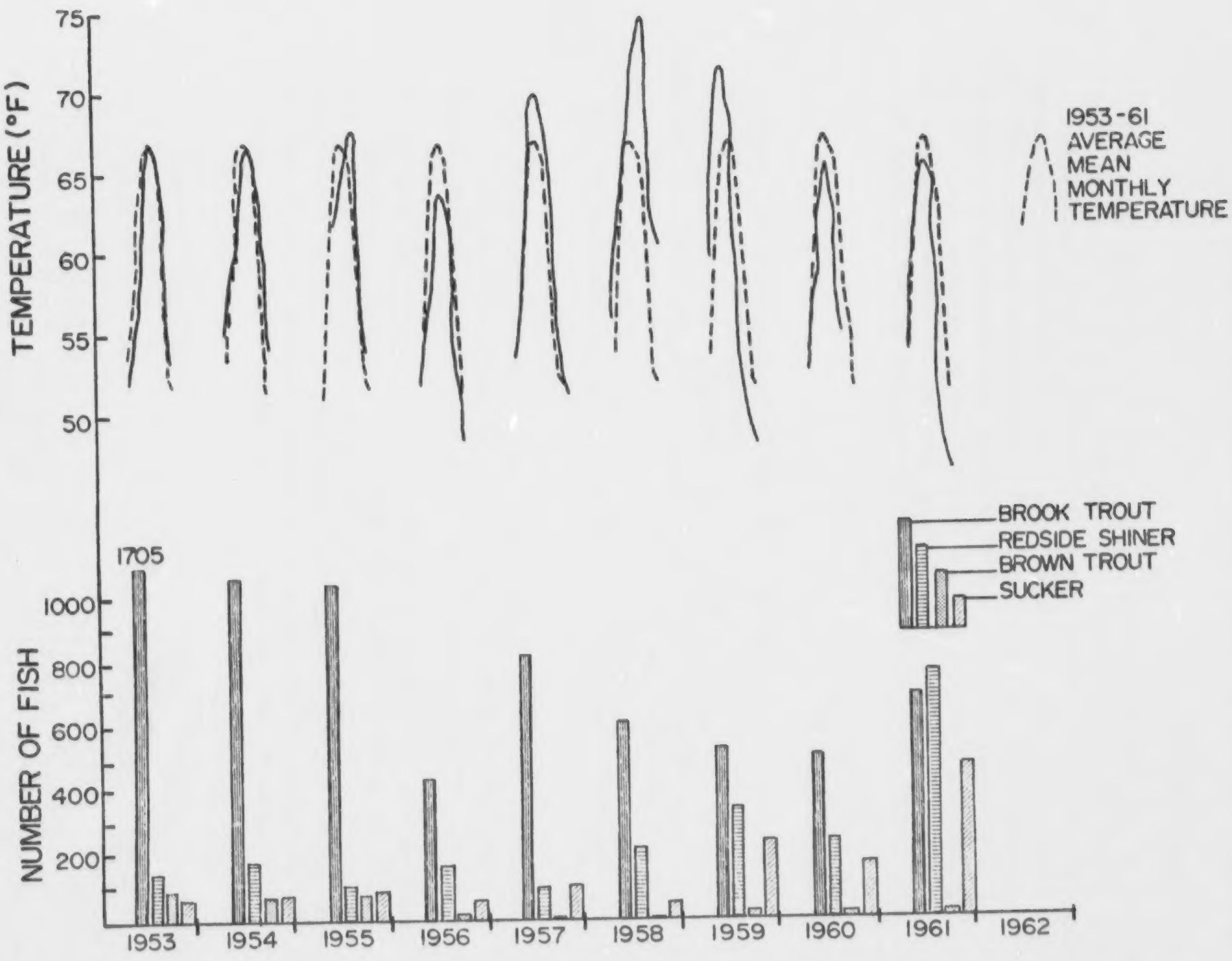

Figure 19. Historical mean monthly maximum temperatures of the Sagehen Creek (May-October), with the number of fish present.

distribution of selected species which have been encoded in the fish-temperature data base and which are prominent in the literature. It is hoped that the methodology of this analysis may provide a basis from which additional analyses of this or other river systems may be devised.

Selection of a River System

The Mississippi River system was selected as a case study because: (1) It spans a wide range of temperature regimes from its source at Lake Itasca in Northern Minnesota to its mouth at Head of Passes, Louisiana. (2) It spans seven major USGS isotherm zones and a wide latitudinal range. (3) There is a noticeable phase shift in the temperature regimes. (4) It is an important commercial fishing, sport fishing and recreational resource and as such is economically important to ten different states. (5) It is a suitable habitat for at least 35 of the 50 species of fishes selected for detailed analysis. and (6) It has a suitable matched series of fish and temperature data sets.

Mississippi River Description

The Mississippi River originates in Northern Minnesota at 47° north latitude and flows 2,470 miles in a southerly direction. At the mouth, it empties into the Gulf of Mexico at 29° north latitude. The river system drains an area of approximately 1,244,000 square miles including all or parts of 31 states and two Canadian Provinces (Barnickol and Starrett 1951). It travels through, or is the boundary for, the states of Minnesota, Wisconsin, Iowa, Illinois, Missouri, Kentucky, Tennessee, Arkansas, Mississippi and Louisiana.

The headwaters of the river, above the Twin Cities in Minnesota, are intersected by a series of dams and lakes used as water storage for hydroelectric power, navigation and flood control. In free flowing areas it varies from a narrow, slowly meandering stream to a shallow, wide, relatively straight and fast flowing stream. Bottom morphology varies from sand and silt to gravel, rubble and boulders. Turbidity changes occur from one location to another due to the surrounding soil types which vary in erosive properties and because of industrial effluents. The river travels 660 miles through Minnesota with a stream gradient of 1.28 feet per mile, while the average stream gradient for the entire Mississippi is 0.57 feet per mile (Johnson 1968).

From its confluence with the Missouri River to Hastings, Minnesota, the upper Mississippi River consists of a series of 26 locks and dams. This segmentation has essentially transformed the upper river into a series of pools or small lakes, but between these impoundments, there are stretches of the river which exhibit considerable current. The impoundment of the river has had the effect of creating stable water levels and a rich and varied aquatic environment. Below Alton, Illinois, the Mississippi has remained free flowing for the entire distance to the Gulf of Mexico. Turbidity in this portion of the river is much greater than in the upper reaches. This is due, in part, to the high silt load added by the Missouri River; however, the relatively clear Ohio River tends to dilute these turbid waters below its confluence with the Mississippi (Pflieger 1971).

Below the confluence of the Missouri River, the current of the Mississippi increases in velocity and flows over a common substrate of fine sand, gravel and occasionally rubble. This bottom type remains virtually unchanged from this point to the Gulf of Mexico except for the silt bottoms of the occasional backwater areas (Pflieger 1971).

The total water quality of the Mississippi is a consequence of multiple-use demands of a growing human population, industry, and agriculture. In Louisiana alone, nearly five-billion gallons per day of river water is withdrawn for municipal and industrial uses (Everett 1971). The river is also used as a vehicle for disposal of organic and inorganic wastes. Thermal waste water from industrial cooling and electric generating plants also has an effect on the river environment. The suspended solids and soil particles causing turbidity in the river are in large measure a consequence of the intensified farming activities which proliferate throughout the watershed.

The spectrum of climate along the Mississippi River varies from the severe cold winters and short hot summers, which are typical of Minnesota's continental climate, to the short, mild winters and long hot and humid summers, which characterize the subtropical environment of Louisiana.

Description of the Temperature Data

Data were collected for 66 locations on the Mississippi River; however, not all of these stations contained both fish and temperature information. For the most part these two types of data were collected by separate agencies who were utilizing the data for their own purposes. For this reason fish and temperature sampling periods and locations differed extensively throughout the river system.

The Upper Mississippi River Conservation Committee (UMRCC) has documented fish population changes in the Mississippi above the Ohio River since the early 1940's. Fishery information available for the stretch of river below Caruthersville, Missouri, was from commercial catch statistics supplied by the National Marine Fisheries Service (NMFS, U.S. Department of Commerce 1972) and a three year pollution study (U.S. Department of the Interior 1969) in the lower Mississippi River basin. In addition, the University of Louisiana supplied notes on the relative abundance and field observations of reproductive phenomena of fishes in the river near St. Francisville.

The commercial fish records supplied by the NMFS were limited in value since they grouped similar species such as buffalofish and crappie, and summarized the location of each catch by state. The summarization of catch statistics by state created encoding problems such as defining the latitude-longitude relationship of the U.S. Geological Survey (USGS) isotherm map designation and major and minor river basins. The selection of a location for the fish data added to the confusion of matching temperature stations to this data. Additionally, information on the fish sampling method was seldom reported by type of sampling gear but rather was reported by all types of gear used. Out of 243 fish-temperature data sets available by all types of sampling methods, 185 were in category 14, "combination". A further complexity in the compilation of catch statistics was that fish counts were reported in a variety of units such as pounds, percent, number per day, number per year or number of each species caught.

The reporting of temperature sampling locations was more precise than the reporting of fishery locations. The location of temperature data was often given by latitude-longitude coordinates while geographical names (lakes, rivers, cities, etc.) were used for reporting fish sampling statistics. However, most temperature monitoring stations on the Mississippi River system were associated with larger cities and were supplied by the USGS or the U.S. Army Corps of Engineers. These data represented the longest-term records; whereas, municipal intake water temperatures were, for the most part, sporatic and not readily available except in summary publications. Limitations to the temperature data, however, were associated with a lack of correlation to depth and a lack of uniformity in sampling time. Much of the data on river temperatures were obtained from the USGS Data Base, and for these data the type of temperature sampling equipment was not given. There were 145 fish-temperature data sets out of a total of 221 in which the temperature sampling equipment is not known.

With such a large mass of information collected on the Mississippi River and as the true location of some of the data measurements were vague, it was important to establish a geographical locus, with stations on the river. A table was developed to list in downstream order, the stations, there locations and years of record of fish or temperature data. This information was then annotated on a large map of the Mississippi River showing the locations of fish and temperature stations where data was collected or known to exist. Figure 20 is a reduced representation, but does not indicate all stations from the table or the larger map.

It was apparent from the table and map that some locations contained only temperature data, others contained only fish data, and in many areas neither type of data existed in the computer base. Consequently, an additional effort was made to obtain data in these categories and locations. For example, neither fish nor temperature data were present above Monticello, Minnesota. Intensified data collection efforts in this area culminated in three additional fish data sets and seven additional temperature data sets.

Since the stations should contain complete fish-temperature data sets from the same location and time period for this study, and since this requirement could not be achieved for the entire Mississippi River data base, the philosophy of data collation was altered. Several options were available: (1) Include only those stations that had complete fish-temperature data sets. (2) Include all available data and analyze only those stations that were complete data sets. and (3) Include all available data and manipulate the temperature data so that all of the fish data would have a matching temperature set. For this analysis, option three was employed and the following discussion describes the manipulated method.

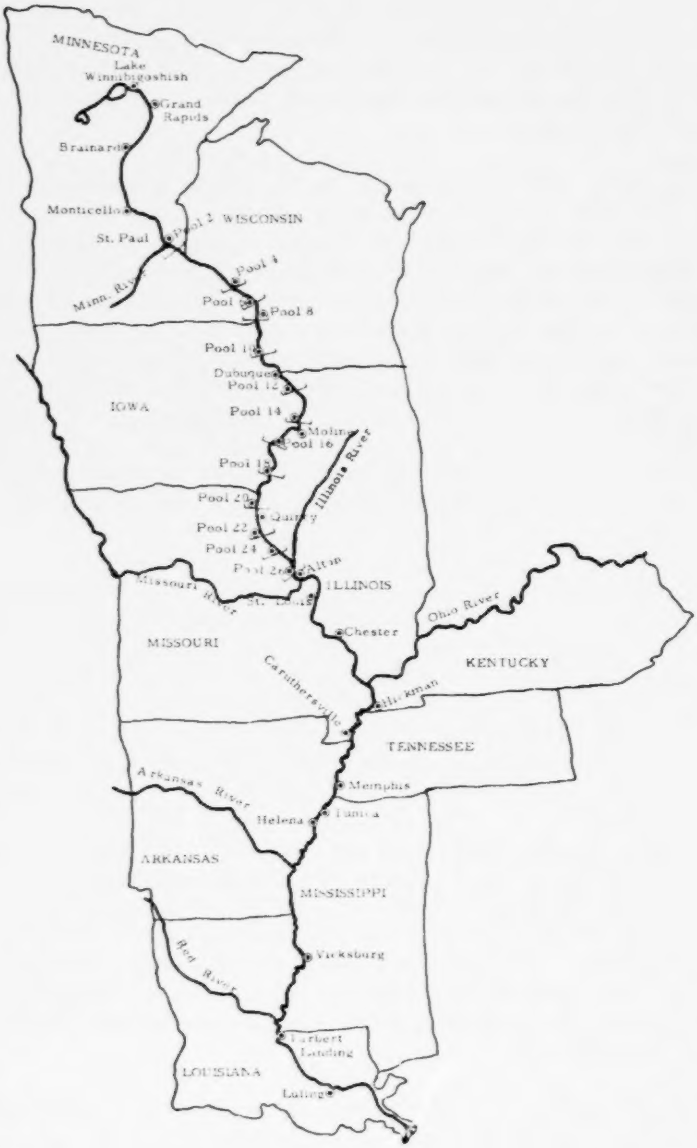
MINNESOTA
Lake Winnibigoshish
Grand Rapids
Brainard
Monticello
St. Paul
Pool 2
WISCONSIN
Minn. River
Pool 4
Pool 8
Pool 8
Pool 10
Dubuque
Pool 12
IOWA
Pool 14
Moline
Pool 16
Illinois River
Pool 18
Pool 20
Quincy
Pool 22
Pool 24
Pool 26
Alton
ILLINOIS
Missouri River
St. Louis
Chester
Ohio River
MISSOURI
KENTUCKY
Caruthersville
Hickman
TENNESSEE
Arkansas River
Memphis
Helena
Tunica
ARKANSAS
MISSISSIPPI
Vicksburg
Red River
Tarbert Landing
LOUISIANA
Luling

Figure 20. Mississippi River Basin map.

In order to justify the merging of temperature data at one location with fish data at another location and thereby "create" a fish-temperature station, visual interpretation of the thermal regimes covering the river system was needed. Thus a temperature station was selected from each of the seven USGS isotherm bands which intersect the Mississippi and the average monthly temperatures for selected years of record were plotted. The stations selected for review are shown in downstream order by isotherm in Figure 21. The additional station at St. Louis (isotherm 55-59 F) (12.8-15.0 C) was added to compare the influence of the Missouri River to temperatures recorded at Alton, immediately upstream.

As expected, the river warms as it flows southward. The degree of warming from one location to another, among others, is a function of the climatology, industrial use of the river, geography and the influence of tributary streams. Monthly temperatures varied as little as 2 F (1.1 C) between adjacent isotherms and as much as 10 F (5.6 C) depending on the season of the year and the location. Additionally, temperatures were more variable between the northern stations than between southern stations. For example, the average monthly temperatures in April for Jacobson were from about 34-42 F (1.1-5.5 C), while those at St. Paul were about 44-51 F (6.7-10.6 C). Differences in the lows and highs between these stations were 10 and 9 F (5.6 and 5.0 C), respectively; whereas, the differences in the low and high average monthly temperatures between Helena and Tarbert Landing for April were only 4 and 1 F (2.2 and 0.6 C), respectively.

A marked phase shift in temperature occurred between the extreme northern and southern stations. In comparing records between St. Paul and Tarbert Landing, temperatures warmed as much as a month earlier at Tarbert Landing and cooled as much as a month later than at St. Paul. The determination of the influence of the Missouri and Ohio Rivers on the thermal regime of the Mississippi was not attempted; however, it was noted that the temperatures at St. Louis were slightly cooler during the spring and summer months and slightly warmer during the winter than those at Alton, immediately upstream.

It was concluded that separate temperature-only stations could be merged with existing fish-only stations with minimum error if they were within the same USGS isotherm zone. However, due to a paucity of temperature data for some stretches of the river, this method was not always applied, and in certain instances, extrapolated temperatures overlapped continguous isotherm boundaries. To ensure that they retained their identity, original temperature and fish records were encoded as incomplete data sets as indicated in Table 30.

Figure 22 represents the means of extreme low and high values of the average monthly temperatures for each season of the year. This figure gives a graphical representation of the thermal regime by latitude and by station on the Mississippi River. The winter season high temperatures can differ as much as 20 F (11.1 C) between the northern and southern latitudinal limits of the Mississippi. The abrupt increase in temperature between Jacobson and St. Paul of 6 F (3.4 C) and then the rapid 4 F (2.2 C) cooling at Dubuque may be from the high industrial use of the river in the area surrounding

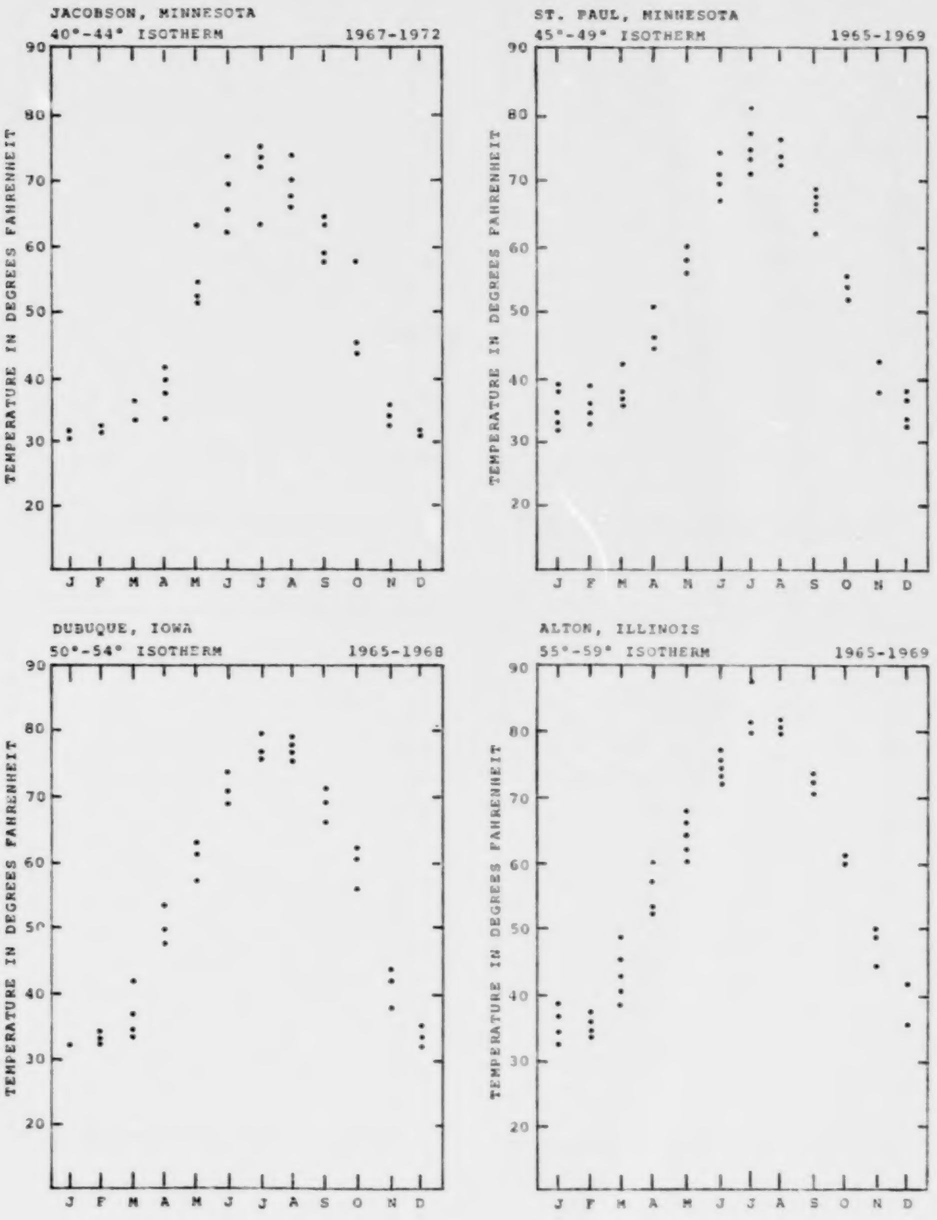

Figure 21. Average monthly temperatures for stations on the Mississippi River for selected years of record.

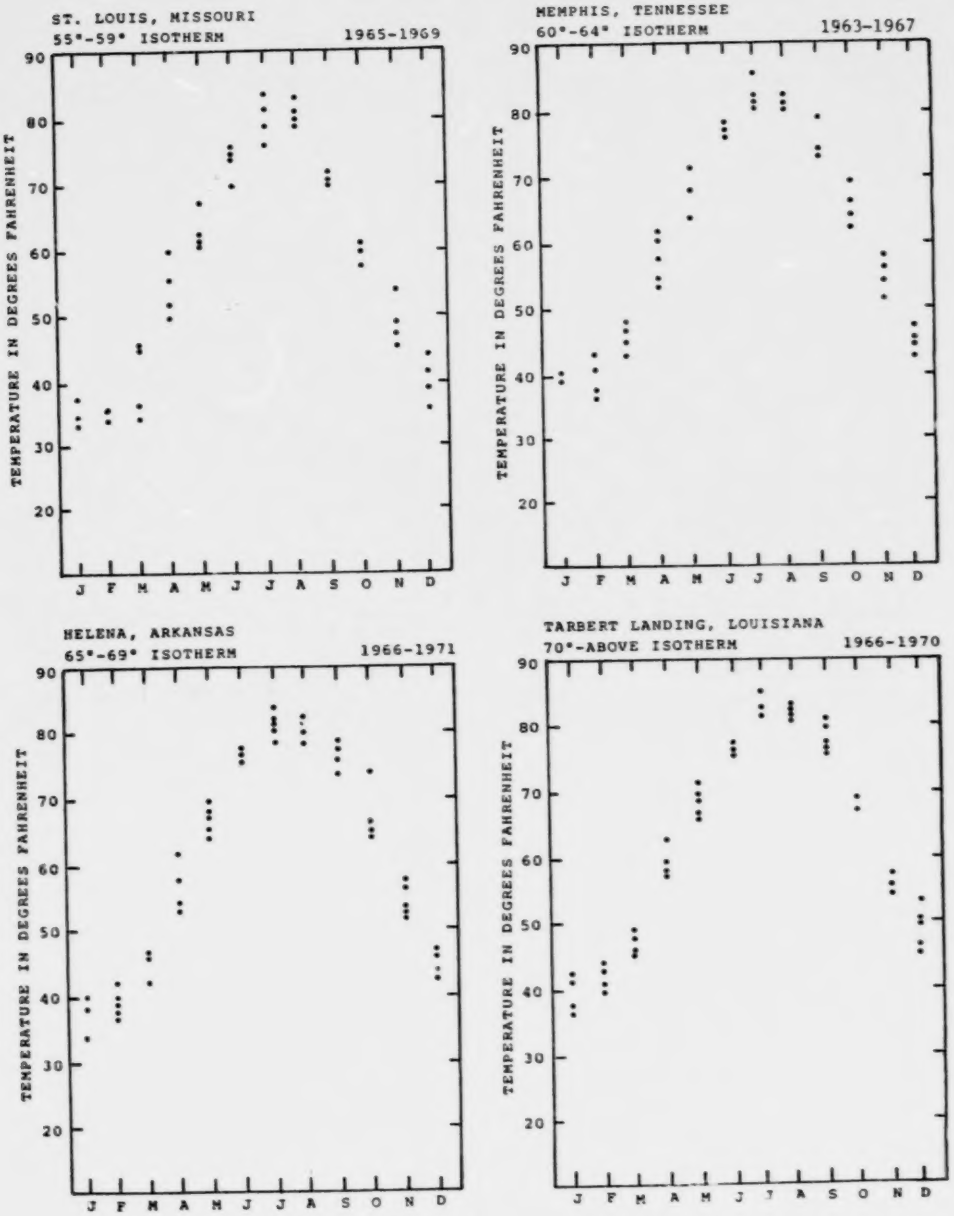

Figure 21. (continued)

TABLE 30. MISSISSIPPI RIVER STATIONS

	Station	F	T	Downstream Order	F = years of fish records Y = years of temperature records
1	260600	X		State of Minnesota	F = 1949-62
2	260707		X	Mississippi River at Grand Rapids, MN	T = 1967-72
3	260706		X	Mississippi River at Jacobson, MN	T = 1967-72
4	260705		X	Mississippi River at Camp Ripley, MN	T = 1967-72
5	260704		X	Mississippi River at Royalton, MN	T = 1967-72
6	260703		X	Mississippi River at Sauk Rapids, MN	T = 1953-65
7	260702		X	Mississippi River at St. Cloud, MN	T = 1967-72
8	260701		X	Mississippi River at Clearwater, MN	T = 1967-71
9	260504	X		Minnibigoshish to Grand Rapids	F = 1961
10	260503	X		Grand Rapids to Brainard	F = 1965, 1967
11	260505	X		Brainard to Elk River	F = 1965
12	260203	X	X	Monticello, at River Mile 0.8 from Plant	F = 1968-70 T = 1968-70
13	260204	X	X	Monticello, at River Mile 1.0 from Plant	F = 1968-69 T = 1968-70
14	260200	X	X	Monticello, at River Mile 1.1 from Plant	F = 1968-70 T = 1966-70
15	260202	X	X	Monticello, at River Mile 1.2 from Plant	F = 1968-70 T = 1968-70
16	260201	X	X	Monticello, at River Mile 1.5 from Plant	F = 1968-70 T = 1968-70
17	260500	X		Pool 2 - Minneapolis to Hastings, MN	F = 1964
18	260700		X	- St. Paul, MN	T = 1959-69
19	562000	X	X	Pool 3 - Hastings to above Red Wing	F = 1964-70 T = 1939-48
20	562001	X		Pool 4 - Red Wing to Alma, WI (Lake Pepin)	F = 1945, 1962-70
21	562002	X	X	Pool 4a- above Lake Pepin	F = 1964-70 T = 1939-48
22	562003	X		Pool 5 - Alma to above Minneiska, MN	F = 1945, 1962-70
23	260501	X		Pool 5a- Minneiska to Goodview, MN	F = 1964-70
24	260502	X		Pool 6 - from above Winona, MN to Trempealeau, WI	F = 1945, 1964-70
25	563000	X		State of Wisconsin	F = 1949-59
26	562004	X		Pool 7 - Trempeauleau to above La Crosse	F = 1945, 1962-70
27	562005	X		Pool 8 - La Crosse to Genoa	F = 1945, 1962-70
28	562006	X		Pool 9 - Genoa to below Lynxville	F = 1945, 1964-70
29	180500	X		State of Iowa	F = 1949-59
30	180400	X	X	Pool 10 - Harpers Ferry to Guttenberg, IA	F = 1945, 1964-70
31	562007	X		Pool 11 - Guttenburg to Dubuque	F = 1945, 1962-70
32	180401	X		Pool 12 - Dubuque to Bellvue	F = 1946, 1950, 1964-70
33	180600		X	- Dubuque, IA	T = 1957-69
34	180402	X	X	Pool 13 - Bellvue to above Clinton	F = 1946-50, 1962-68, 71 T=1957-70
35	180403	X		Pool 14 - Clinton to La Claire	F = 1946, 1950, 1964-68, 1971
36	180404	X		Pool 15 - La Claire to Davenport	F = 1945, 1950, 1964-68, 1971
37	161206		X	- Moline, IL	T = 1951-60
38	180405	X		Pool 16 - Rock Island, IL to Muscatine, IA	F = 1945, 1950, 1964-68, 1971
39	180406	X		Pool 17 - Muscatine to New Boston, IL	F = 1946-50, 1964-68
40	161200	X		Pool 18 - New Boston to above Burlington, IA	F = 1946, 1962-71
41	180407	X		Pool 19 - Burlington to Keokuk	F = 1946-50, 1964-68, 1971
42	280500	X		State of Missouri	F = 1946-62
43	280400	X		Pool 20 - Keokuk to Canton, MO	F = 1944, 1950, 1964-68, 1971
44	280401	X		Pool 21 - Canton to Qunicy	F = 1944, 1950, 1964-68, 1971
45	161205		X	- Quincy, IL	T = 1951-60
46	280402	X		Pool 22 - Quincy to Saverton	F = 1944, 1950, 1964-68, 1971
47	280403	X		Pool 24 - near Louisiana, MO	F = 1944, 1950, 1964-68, 1971
48	280404	X		Pool 25 - Louisiana to Winfield, MO	F = 1944, 1950, 1964-68, 1971
49	161201	X		Pool 26 - Winfield to Alton, IL	F = 1944, 1950, 1962-68, 1971
50	161207		X	- Alton, IL	T = 1951-60
51	161202	X		State of Illinois	F = 1949-52
52	280600		X	- St. Louis, MO	T = 1951-70
53	161203	X	X	Pool 26b- St. Louis to Caruthersville, MO	F = 1944, 1964-68, 1971 T=1951-70
54	161204		X	- Chester, IL	T = 1952, 1960-69
55	200301	X		State of Kentucky	F = 1950, 1954-68
56	200300	X	X	- at Hickman	F = 1966, 1967, 68 T = 1956-71
57	470200	X		State of Tennessee	F = 1950, 1954-59
58	470201		X	- at Memphis	T = 1956-71
59	271500	X		State of Mississippi	F = 1954-62, 1967
60	271400	X		- at Tunica, MI	F = 1966, 1967, 1968
61	040900	X		State of Arkansas	F = 1950
62	040700		X	- at Helena	T = 1957-71
63	271401	X	X	- at Vicksburg, MI	F = 1966, 1967, 1968 T = 1959-68
64	211400	X		State of Louisiana	F = 1950, 1964-68
65	210100	X	X	- at Tarbert Landing	F = 1966-68 T = 1966-71
66	210101	X	X	- at Luling	T = 1959-69 F = 1966-68

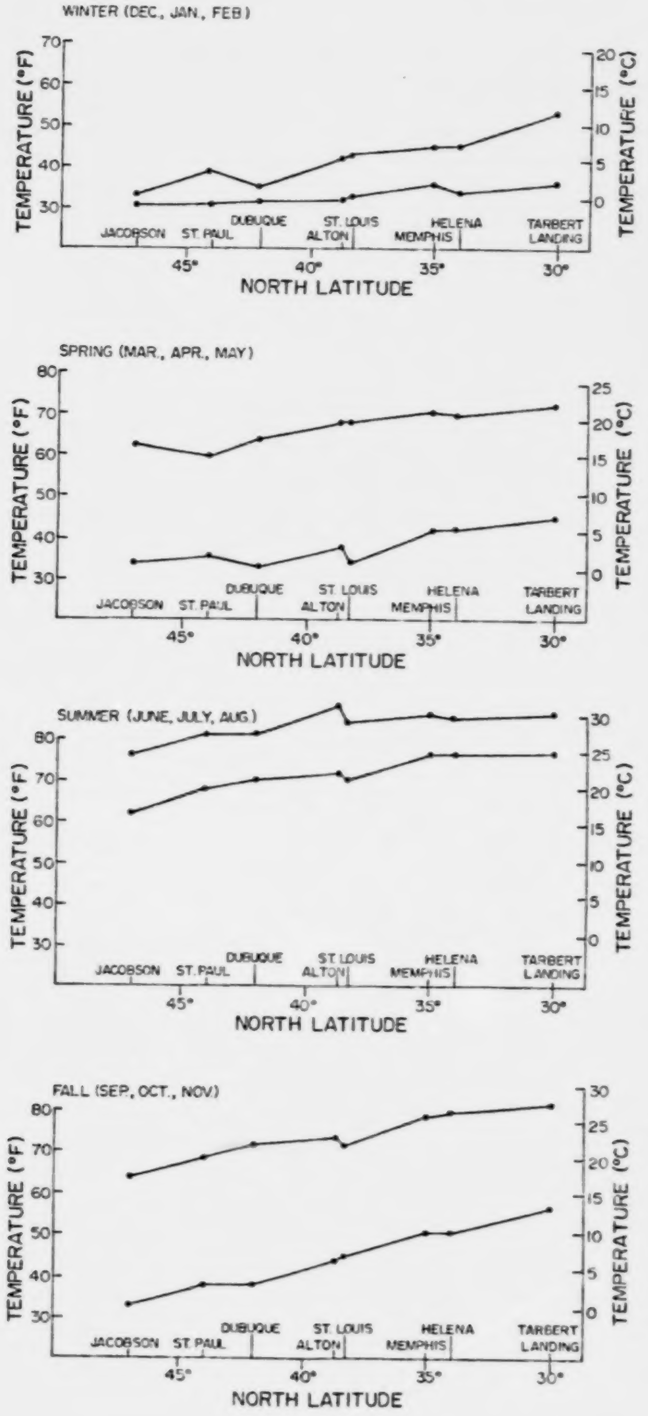

Figure 22. Seasonal extreme temperature values for changes in latitude along the Mississippi River for selected years of record, 1965-1972.

St. Paul. Figure 22 represents six (or less) years of accumulated data for each station, longer-term data would more accurately describe these local conditions. The temperature during spring on the Mississippi fluctuates widely between March and May at each station. The warming of the river below St. Louis appears to be more predictable than in the higher latitudes. Seasonal highs tended to decrease between Jacobson and St. Paul while the seasonal lows increased. South of St. Paul, lows decreased and are 1 F (0.6 C) cooler at Dubuque than at Jacobson.

During the summer season, the differences between the highs and lows at each station are between 9 F (5.0 C) and 14 F (7.8 C). Temperatures increase 5-6 F (2.8-3.4 C) from Jacobson to St. Paul while the temperatures do not vary more than 1 F (0.6 C) in the three most southern stations.

The fall season temperatures depict the cooling of the river as winter approaches. The cooling in the northern portions of the river is much more pronounced than in the southern sections and is most likely a result of latitudinal separation of the two extremes. The seasonal highs in the fall occur in September while the lows occur in November. During this season temperature differences between highs and lows at each station varied from 25-34 F (13.9-18.9 C).

In summary, this section of the report has described a method used to both analyze and synthesize water temperature data in the Mississippi River system. For the most part, temperature records were added to fish stations when these data were lacking and if these data were judged as being representative of the same isotherm. Sample temperature stations from seven USGS isotherm zones were hand-plotted to determine the thermal profile of the Mississippi River. Extreme seasonal variations in temperature indicate that the river is as much as 20 F (11.1 C) cooler in the north during winter and 10 F (5.6 C) cooler during summer than in the south.

Description of the Fish Data

This section will address the relative abundance and distribution of 35 selected species of fishes that are present in the Mississippi River. Consideration is given to the distrubution of these fishes in relation to habitat preferences and other environmental factors where this information was available.

The complexity of environmental conditions existing in the Mississippi is reflected in the diversity of the fish fauna, which includes over 120 known species representing 25 families of fish (Nord 1967). For the purpose of this study, only 50 species were considered for analysis. Of the 50 selected species of fish, 35 of these were found in this river. Table 31 is a composite summary of these fish indicating their abundance as discussed in the literature and from the computer data base. The occurrence of each species is noted by an "X" for the appropriate station location on the Mississippi. Pool 26B, as identified in the table, is that section of the river from pool 26 south to Caruthersville, Missouri.

TABLE 31. DISTRIBUTION OF SELECTED FISH SPECIES IN THE MISSISSIPPI RIVER FROM MINNESOTA TO LOUISIANA
1944 - 1968

Minnesota
Wisconsin
Iowa
Missouri
Illinois

Species		***	Winnibigoshish to Grand Rapids	Grand Rapids to Brainerd	Brainerd to Elk River	Elk River to Pool 2	Upper Mississippi River Navigation Pools																									Hickman, Ken.	Tunica, Miss.	Vicksburg, Miss.	Tarbert Landing, La.	Luling, La.	Level of abundance (Nord 1967 and Smith, et al 1971)
							2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	24	25	26	D 26						
003	Gizzard shad							X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X	X	Abundant throughout river
004	Treadfin shad																														X	X	X	X	X	X	Common below Ohio River, uncommon above
005	Lake whitefish		X	X																																	
013	Rainbow trout											X		X	X																						Accidental, rare
019	Chain pickerel																															X			X		
020	Northern pike		X	X	X		X	X	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X			X						X				Common above Pool 11, occasional to Ohio River
021	Muskellunge		X	X	X									X	X							X										X	X	X	X	X	Based on old records; probably does not now occur in this river below Pool 2
022	Carp (European)				X			X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X						Abundant
023	Fathead minnow		X				X	X	X	X	X		X	X									X								X						Uncommon, but occurs throughout
025	White sucker		X	X	X		X	X	-	-	-	-	-	-	X	X	X				X			X													Widely distributed above Pool 12, less so below
026	Smallmouth buffalo							X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X	X	Rare above Pool 12, common below
027	Bigmouth buffalo							X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X	X	Moderately common
028	Black bullhead		X	X			X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X	X	Widely distributed but not common
029	Yellow bullhead		X	X	X			X	-	-	-	-	-	-	-	X		X			X	-	-	-	-	-	-	X	X	X	X			X	X	X	Widely distributed but not common
030	Brown bullhead		X	X			X	X	-	-	-	-	-	-	-	X		X												X	X		X	X	X	X	Widely distributed but not common
031	Channel catfish						X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X	X	Common throughout
032	White bass							X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X	X	Common throughout
034	Green sunfish						X	X	X	X	X		X	X		X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X						Widely distributed but not common
035	Bluegill		X	X	X		X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X	X	Abundant throughout
036	Smallmouth bass		X	X	X		X	X	-	-	-	-	-	-	-	-	-	-	-	X	X		X		X			X			X						Rare below Pool 17
037	Largemouth bass		X	X			X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X	X	Common throughout
038	White crappie							X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X	X	Common throughout
039	Black crappie		X	X	X		X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X	X	Common throughout
040	Yellow perch		X	X	X		X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X			X										Locally common above Pool 19
041	Sauger						X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X		Common, especially below Missouri River
042	Walleye		X	X	X		X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X							Less common below Pool 20 than above
043	Freshwater drum							X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X	X	Common throughout, but particularly abundant below Missouri River
090	Mosquitofish																X												X	X						Occasional below Pool 24
091	Golden shiner		X	X			X	X	-	-	-	-	-	-	-	-	-	-	X		X	-	-	-	-	X			X		X		X	X			Widely distributed, but not common
103	Redear sunfish																																		X	X	Accidental to upper river
109	Flathead catfish						X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X		X	X	X	X	X	Common throughout
113	Shovelnose sturgeon							X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X		X	Occasional from Lake Pepin to Ohio River
114	Lake herring (Cisco)											X																									Rare
115	Emerald shiner						X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X						Most abundant fish in river

Of primary importance is the influence of water temperature on the distribution of selected fishes in the Mississippi. For many species, water temperature has been identified by field and laboratory research as a limiting factor in distribution and abundance in river systems. Other factors correlated with species distribution include river morphology, pollution, interspecific competition, food habits, spawning preferences, climate, man-made changes in local habitats, and seasonal migrations.

Environmental factors, for the most part, are not independent variables and where the patterns of variation for two or more factors are correlated, it is not easy to demonstrate that any one factor is dominant in controlling the distribution of a given species. Many of the more obvious physical and biological factors have been studied in hopes of gaining more understanding on how they interact with specific fish; however, it should be remembered that in some instances more subtle and less readily observed factors may be of greater importance (Pflieger 1971).

One of the principal factors associated with the changes in fish species in the Mississippi River is man's alteration of the aquatic environment. Carlander (1954) reported that construction of dams along the river have become barriers to upstream migration of paddlefish (Polyodon spathula), American eel (Anguilla rostrata), buffalofishes, skipjack, Ohio shad (Alosa ohienais), and freshwater drum (Apolodinotus grunniens). In addition, spawning grounds have been destroyed for species such as the skipjack, Ohio shad and blue sucker (Cycleptus elongatus). On the other hand, such impoundments may have produced a favorable habitat for species such as the largemouth bass, channel catfish, white crappie (Pomoxis annularis), black crappie (Pomoxis nigromoculatus) and bluegill (Lepomis macrochirus) that are characteristically associated with lentic habitats. Other factors such as leveeing of river banks, destruction of habitats through efforts to maintain a navigation channel and siltation caused from deforestation have contributed to the changes in the numbers and distribution of fish (Smith et al. 1971).

The man-made changes and modifications in the upper Mississippi River above Alton have changed the current velocity, turbidity and bottom type. Prior to man's development of the Mississippi for navigation, the river consisted of a series of relatively deep pools separated by shallow bars, rapids, and a fluctuating water level. Impoundment has brought an increase in the permanent water area, and a decrease in current and water level fluctuation. The reduction in the river current has been accompanied by a corresponding reduction in turbidity, although this could be offset by increased erosion. With the precipitation of silt, sand, gravel and rubble, the river bottom is covered and thus tends to limit the area of suitable spawning habitat that certain species of aquatic life require. Carlander (1954) concluded that due to the paucity of information in early fish collections prior to man's activities on the Mississippi River, it is difficult to assess the full impact of many of these changes.

DISTRIBUTION AND TEMPERATURE REGIMES FOR CHANNEL CATFISH

The distribution of channel catfish, as included in the data base, is given in Table 32 for streams and rivers. Figure 23 is a graphic presentation of this data.

TABLE 32. THE NUMBER OF FISH-TEMPERATURE DATA SETS FOR CHANNEL CATFISH IN STREAMS AND RIVERS BY MAJOR AND MINOR RIVER BASIN AND STATION CODE

River basin codes		Station	Total number of fish-temperature data sets
Major	Minor		
2			5
	3		1
		410105	1
	14		4
		230900	4
3			9
	1		2
		361000	1
		361001	1
	31		1
		110200	1
	42		5
		270600	1
		270700	1
		270800	1
		270801	1
		271201	1
	43		1
		271100	1
4			23
	6		10
		470401	5
		470403	5
	7		5
		470800	5
	8		8
		470700	5
		470500	2
7			35
	4		1
		260500	1
	5		11
		260101	3
		260102	3
		260103	3
		260104	2
	7		9
		562001	3
		562003	2
		562004	2
		562007	2
	10		3
		180402	3
	17		4
		161200	1
		161201	3
	18		7
		280500	7
9			8
	9		4
		300100	4
	11		1
		191200	1
	12		3

(continued)

TABLE 32. (continued)

River basin codes		Station	Total number of fish-temperature data sets	River basin codes		Station	Total number of fish-temperature data sets
Major	Minor			Major	Minor		
					12		
		470701	3			300300	2
5			3			300400	1
	14		1	10			29
		200800	1		5		8
	20		2			40600	3
		40601	2			490101	3
		280100	1	12			15
		280101	1		1		9
		280102	1			210800	1
	6		5			210801	1
		200300	3			210802	1
		271400	2			210803	1
	11		5			210804	1
		270300	1			210805	1
		270400	1			210807	1
		270401	3			210808	1
	16		3			210814	1
		390700	2		5		3
		390701	1			482200	1
	19		2			482202	1
		210200	2			482204	1
	20		1		7		3
		210600	1			480800	2
	21		5			480900	1
		210100	3	13			39
		210101	2		8		8
11			8			540105	8
	2		1		10		31
		340100	1			540101	9
	6		7			540102	9
		490100	4			540104	13

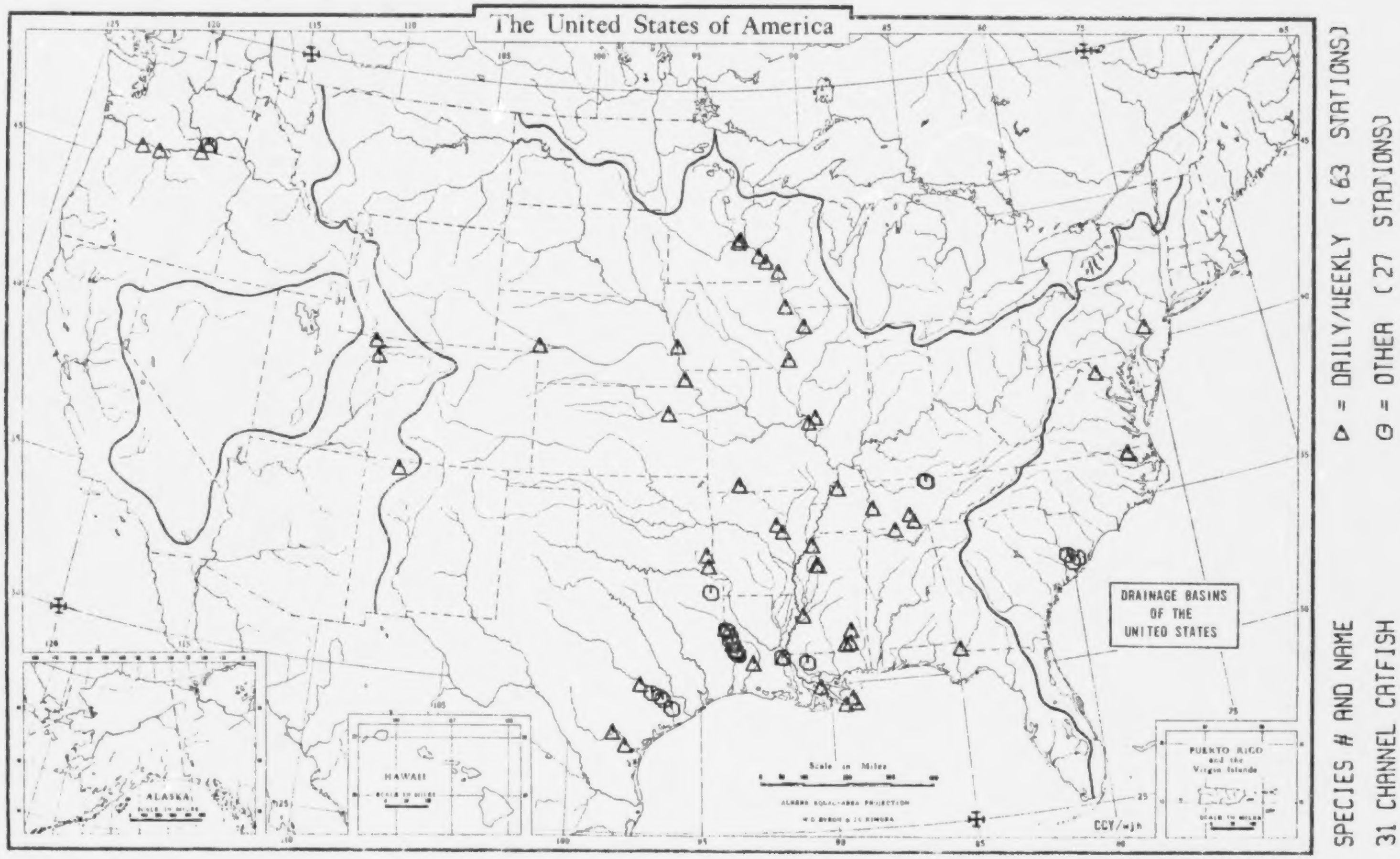
The United States of America
DRAINAGE BASINS OF THE UNITED STATES
ALASKA
HAWAII
PUERTO RICO and the Virgin Islands
Scale in Miles
CCY/wjh
SPECIES # AND NAME
31 CHANNEL CATFISH
Δ = DAILY/WEEKLY (63 STATIONS)
ʘ = OTHER (27 STATIONS)

Figure 23. Location and number of stream river stations where channel catfish were present.

To describe the temperature regimes inhabited by channel catfish, we selected only stream and river stations which are more isothermal (i.e., the temperature is not stratified with depth) than lakes or reservoirs. The spatial and temporal presence of channel catfish in these water bodies suggest that all life phases tolerate the upper and lower temperature extremes found during different seasons. We assume that temperatures are adequate to permit reproduction, embryo and larval development, growth, and maturation at appropriate times during the annual temperature cycle. Accepting these assumptions we obtained a computer printout of all temperature records where channel catfish were present in stream and river stations, and examined the data for accuracy and completeness. Several computer options are available for further description of the seasonal temperature regimes where channel catfish were present. (See Figures 3, 4, and 8 etc.) Temperature records obtained over the geographical range of a species should theoretically approximate their thermal tolerance limits for all life functions. A statistical summary of the temperature envelope was desired to collate to thermal requirements established in laboratory bioassays. Therefore weekly mean temperatures from all stations (years) where channel catfish were present were summarized by the cummulative frequency of occurrence of the temperatures in the data base (to perform this analyses, computer programs STWKLY, CFT, FTT, WKTTAB, WKPCT1 and WKPCT2, outlined in Table 3, and discussed in Section 4 were used). The seasonal temperature regime to which channel catfish were most frequently reported in the data base is described by a seasonal envelope bound by the 5, 50, and 95 cummulative percentile of occurrence of weekly mean temperatures in the data base. The temperatures between the 5 and 95 cummulative percentile values indicate that ninety percent of the channel catfish found in rivers and streams included in the data base are found within this range. The output from program WKPCT2 for channel catfish is hand plotted in Figure 24. Of all weekly mean temperature values in the data base in the stream-river category where channel catfish were present, only 5 percent were higher than the upper envelope and 5 percent were lower than the lower envelope. The weekly mean temperatures were below 10 C for 12 weeks and not above 30 C during the two warmest weeks of summer in the upper envelope (95 percentile). In the lower envelope (5 percentile), the weekly mean temperature where channel catfish were present was below 10 C for 29 weeks and reached a high of 18 C during the two warmest weeks in summer.

The biological significance of this thermal regime will be discussed in Volume III entitled "Analysis of Thermal Criteria and Temperature Regimes Supporting Stream Fish Populations". Also in Volume III, thermal criteria based largely on laboratory derived requirements are discussed in connection with natural temperature regimes supporting populations of thirty species of freshwater fish. The location and number of stations where each species were present in the data base are plotted on maps of the United States that reflect their geographic distribution.

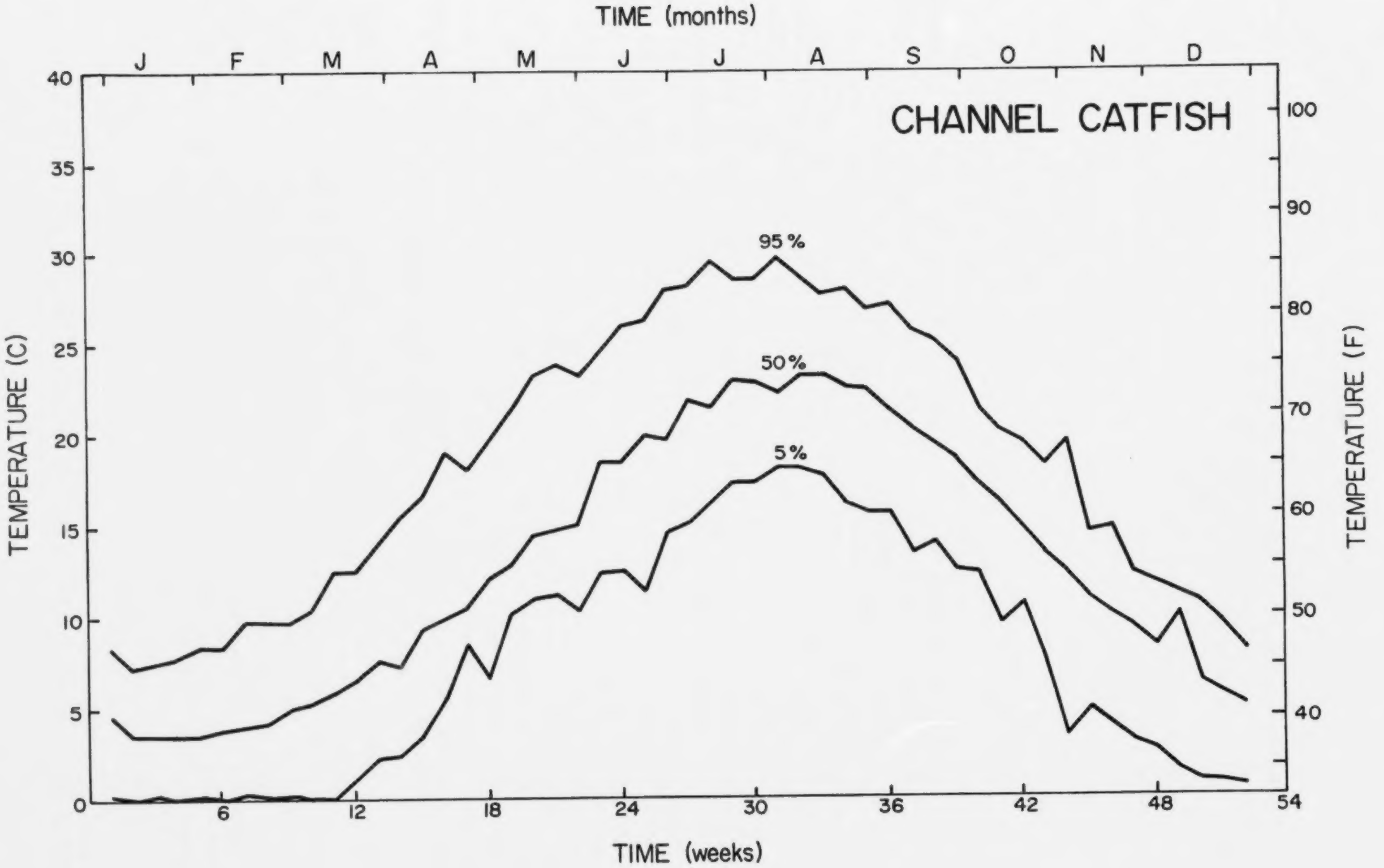

Figure 24. Seasonal temperature envelope by percentage occurrence for channel catfish.

SECTION 7

DATA LIMITATIONS

The purpose of this section is to describe some of the major limitations of the data that have been incorporated in the fish-temperature data base. This discussion is considered essential as experience has shown that the more cognizant that potential users are of the inherent strengths and weaknesses of the basic data, the less likely they are to apply analytical techniques which are inappropriate. Hopefully, through this knowledge, users of the data base will be able to maximize the utility and effectiveness of the derived results.

It should be pointed out that many of the limitations of the data compiled were anticipated and had previously been identified as being a subject that would have to be dealt with in realistic terms.

Throughout the following discussion it should be borne in mind that the two major reasons for the limitations placed on the study data base are: (1) the great variability of methods that were used to obtain and summarize the basic temperature and fish data and, (2) that these data were never originally collected with the present study objectives in mind.

TEMPERATURE DATA

The major sources and types of stream, lake, and reservoir temperature data available were described. As noted, the frequency of these observations range from daily to annual. Additionally, the distribution of these data in both space and time can vary on a regular or random basis depending on the nature of the sampling program. To further complicate the situation, the methods used to obtain the temperature data are nonstandardized and the instrumentation consists of hand-held thermometers, maximum-minimum recording thermometers, continuous recording thermographs, and various types of electronic temperature systems for obtaining vertical thermal profiles of streams, lakes, and reservoirs.

Although all of the foregoing have posed special data collation and processing problems, the most serious limitations of the available temperature data have been the subject of accuracy, or more correctly, the inaccuracy of observations, and the non-standardized computational methods used by various organizations and individuals to present the data in terms of observed ranges, averages, etc.

To avoid confusion in the remaining discussion, the accuracy of a measurement is defined as the ratio of the error of the indicated value to the true value or absolute value, e.g. (indicated value-true value)/true value. In determining the accuracy of an observation, one attempts to eliminate any biases due to operational deviations in the instruments themselves, the observer, or external environmental conditions.

A review of the literature on water temperature data collected revealed that although the situation regarding the uncertainty of the accuracy of the data is generally acknowledged, very few investigators have attempted to analyze the problem to ensure that the compiled data were expressed in a meaningful form and to assist in the appraisal and use of these data. This is especially true for the various temperature data compilations prepared by several states in cooperation with the USGS (Appendix E) and from data obtained from numerous diverse sources. Significant exceptions to the foregoing are found in the publications by Moore (1963, 1964, and 1967); Smith (1962); and Jaske and Synoground (1970). A brief review of various aspects of these papers pertinent to this study follows.

Moore (1963, 1967) reviewed the accuracy of the temperature records compiled for Oregon streams (Moore 1964) primarily in terms of the instruments and methods used by the USGS to obtain their data. He concluded that USGS thermographs, having a rated accuracy of ±1.1 C (±2 F), respectively, can be considered accurate to ±0.5 C (±1 F). This is based on the fact that the USGS hand thermometers used to check the thermographs and obtain spot observations at other locations were graduated in one degree increments which permitted observational errors of one-half of the smallest graduation, or ±0.3 C (±0.5 F). Moore (1967) also stated that with respect to USGS data, "Experience in Oregon has shown that thermomgraph and hand-thermometer observations agree within 0.6 C (1 F) about 80 percent of the time, and within 1.1 C (2 F) about 95 percent of the time". However, he cautioned that unless the thermograph station is carefully sited and periodically checked and adjusted on the basis of hand thermometer observations, the resulting thermograph data can be as much as 1.7 C (3 F) in error. Moore recommended that in order to reduce these errors the stream temperature should be measured by reading the thermometer while it is immersed in moving water near the end of the inlet pipe containing the temperature probe. He did not, however, discuss the possible errors that could be introduced by paralax from reading the thermometer in this fashion. With regard to proper siting of the thermograph or spot observation stations, Moore stressed the need for obtaining vertical temperature profiles across the stream to ensure that the water temperature at the point of observation was representative of the average of all of the observations obtained across the width of the stream.

The validity of following this procedure was pointed out in the case where 38 of 40 USGS thermograph stations in Oregon were found to be within 0.7 C (1.25 F) of the average for the cross-section and for 29 stations within 0.3 C (0.5 F). At all of these stations, care was taken to ensure that the temperature sensor was submerged in moving water at all times.

Jaske and Synoground (1970), from their investigations of the effects of the Hanford Plant operations on the temperature of the Columbia River, also showed the value of properly siting and maintaining thermograph stations in order ". . . to assure that the resulting numerical information and derived judgments represent an objective assessment of the events which have taken place". Data obtained by them from six thermographs of the same manufacturer were checked weekly with an Atkins RTD thermometer having a certified accuracy of ±0.01 C (±0.018 F). The resulting accuracy of the data from the thermograph stations varied between 0.75 C to 0.25 C (1.35 to 0.45 F).

In discussing the feasibility of utilizing spot observations obtained with hand-held thermometers from streams in the Columbia River Basin (Oregon, Washington, Montana, Idaho), for the purpose of computing daily mean water temperatures, Sylvester (1958) concluded that because of the effects of diel heating and cooling of the water temperature at any given location, "no particular hour can be established for a given stream at such time the water temperature will be representative of the daily average temperature". However, both Sylvester (1958) and Moore (1967) agreed that for streams in the Columbia River Basin having a normal diel temperature fluctuation, routine twice daily, spot observations obtained at 7 a.m. and 5 p.m., or 8 a.m. and 4 p.m., gave a good approximation of the maximum, minimum, and mean stream temperature.

Specifically, Sylvester found that the daily average of the spot observations taken at 8 a.m. and 4 p.m. were within about ±1.1 C (+2 F) of the daily average temperature computed from hourly readings at six selected thermograph sites in the Columbia River Basin. Moore (1967) summarized the results of previous attempts at deriving daily mean water temperatures from regular spot temperature observations in other regions of the United States as follows:

> "Meyer (1928, p. 21-22) found that when twice-daily spot observations of water temperature are used, an average of those obtained at 9 a.m. and 9 p.m. give the best estimate of the daily mean water temperature. D. Q. Matejka (oral communication, 1951), in discussing Nebraska streams, concluded that two or three daily temperature observations-- morning and evening or morning, noon, and night —best define the daily mean water temperature. He further concluded that observations at 8 a.m. and 4 p.m. are the most practical and, when averaged, define a temperature that is within 2 percent of the true mean. W. A. James (oral communication, 1951) tested 10 different methods for computing daily mean water temperature of New Mexico streams and concluded that averaging the maximums and minimums for each day produced sufficiently accurate results, with a probable error of 0.57 F."

Smith (1962) also examined the relative dependability of average daily temperatures derived from the daily maximum-minimum temperatures as read from thermograph charts with single spot observations taken daily on two streams tributary to the south shore of Lake Superior during the period from 1958-1960. The time of day at which the hand thermometer readings were taken varied randomly. He found that 10-11-day averages of the two types of data yielded averages that never differed more than ±2.2 C (±4 F) and usually disagreed by less than ±1.1 C (±2 F). In discussing the results he stated that:

> "These disagreements become even less consequential when the limitations of the two methods are considered. Thermograph charts were calibrated in 2° graduations, and the width of the pen line was usually 1° or more. The accuracy of interpretation was probably no closer than 1° or 2°. Furthermore, the precision of these instruments displayed a tendency to vary under field operating conditions. Although the instruments were adjusted frequently, their readings undoubtedly were in error by several degrees at times."
>
> "Pocket thermometers, also, were calibrated in 2° graduations and hence could not be read closer than the nearest ° F. The instruments used were very accurate within their limitations and did not vary in precision. The principal disadvantage of a single reading in computing averages is that it usually does not represent the true mean for the day. Apparently, these variations tend to equalize when used in computation of averages."

The last statement should be taken with caution because in essence what it says is that although the thermograph data are suspected to be in error by several degrees, the 10-11 day averages of the spot observations agree within a few degrees of these erroneous data and, therefore, neither set of data give a real indication of the true average stream temperature.

Water temperature data collected by the USGS and other collecting agencies are tabulated and summarized in a variety of ways. The USGS data are arranged in water-year form which begins October 1 and ends September 30 of the following year. Because the average of daily maximum and minimum water temperatures provides a close estimate of the daily mean, the USGS usually publishes only the observed maximums and minimums for each day and the monthly averages of these values for the thermograph records appearing in their annual streamflow reports. In some cases, if thermograph or spot temperature data were obtained prior to and after the construction of a reservoir immediately upstream, means and extremes are presented for both periods to show the effects of the impoundment.

It should be pointed out that depending on the local method used, the maximum and minimum temperatures obtained from the thermograph records can be either a mean of the observed values in each category or the absolute highest and lowest temperature values (extremes) observed during the day. Unfortunately, documentation describing the actual reporting methods employed by the various reporting agencies are, in most cases, insufficient to evaluate this problem.

Spot temperature observations are usually reported as single daily observations or as monthly arithmetic means without additional reference to the number of samples in these means. Also, the time at which spot observations are obtained may not be given. Maximum and minimum temperature data obtained may not be given. Maximum and minimum temperature data obtained with field thermometers are reported in a manner similar to the observed thermograph maximum-minimum observations, but depending on the local policy, spot observations and thermograph data may not be reported if the total observations are less than 80 percent complete for any given month (Goines 1967).

The utilization of the temperature data compiled during this study for the purpose of producing composite annual temperature profiles and cumulative frequency plots for cases where each of the 50 selected fish species were present was accomplished by generating and accumulating daily, weekly and monthly temperatures from all the various stations and years. In addition to other factors such as those already discussed, a special problem encountered during this process was the evaluation of stations' data representing short-term data series which tend to bias the results of analyses from stations with long-term records. The consideration here is, of course, whether the long-term data more accurately estimates the actual environment and if so, should a weighting algorithm be applied to the short-term data to derive a stochastic composite.

An additional consideration independent of the quantitative character of different data sets is the geographic nature of the observed data. For instance, in comparing the years of record of different stations, it is necessary to also select stations which reflect similar environmental effects. Thus, the variance or standard deviation statistics from stations in similar geographical areas (same population) might infer differences in length of record and recording accuracy; whereas, these same statistics from stations in independent (mutually exclusive) geographical areas would simply reflect seasonal and geophysical differences.

From the foregoing discussion, it is clear that the need exists for the establishment of uniform standards of accuracy for stream, reservoir, and lake temperature measurements. Jaske and Synoground (1970) have succintly summarized this problem in terms of national requirements as follows: ". . . the art of stream temperature management will come of age only when an accepted standard of accuracy and sampling frequency is established for all serious researchers, river users and enforcement personnel to have a common basis in discussion of thermal modification of water quality".

FISH DATA

As in the case of the temperature observations, the major limitations of the basic historical fish data collated during this study stems from two main sources. The first is the inherent selectivity in fisheries sampling gear and the second is the lack of a standardized methodology to document the resulting information. The above weaknesses have caused considerable effort to be expended by the study team in terms of qualifying the fisheries information prior to encoding them for computer processing.

Even a cursory review of the literature substantiates that all types of fish sampling gear are more or less selective for certain species, age groups, and size of fish. Moreover, gear performance can vary according to habitat type, weather, chemical and physical properties of the water, and other variables such as time of day and season in which the sampling program occurs. For instance, Krumholz et al. (1962), in sampling the Ohio River with a variety of gear, reported that, ". . . the size of the mesh in hoopnets, trammel nets, and gill nets will restrict the size of fish that can be taken with those nets. With the otter trawl, the size is restricted by the movement of the boat and the movement of the net across the bottom and also by the sizes of the meshes in the net".

Bonn (1966), in sampling reservoir populations, concluded that the effectiveness of the trawl as a method of collection is limited by the physical condition of the water and the areas where it can be used. Specifically, the sampling area should be free of obstacles and submerged vegetation. Bonn indicated that the best catches occurred in murky or turbid water, simply because in clear water the fish were able to see the trawl and take evasive action.

Rotenone is generally conceded by fishery biologists to be the least selective sampling method; however, as reported by Binns (1967) and Krumholz et al. (1962), some species, such as bullheads, are much more resistant to this chemical than other species. Factors such as anatomical differences among fish species also place limitations on the effective use of rotenone in sampling fish populations for species abundance. For example, some fish species (i.e., darters), which do not have air bladders, will sink to the bottom if not picked up immediately.

One of the problems encountered by biologists in sampling fish populations is determining the dimenisons of an area that must be sampled in order to adequately reflect the actual species composition and abundance. Also, as pointed out by Burns (1966), the number of samples required from a given area to adequately describe the fish population within prescribed statistical limits is critical. Too few or too many samples can lead to erroneous interpretation of the data and therefore make the entire sampling effort meaningless. This situation has been underscored by the work of Krumholz et al. (1962) who showed that because of both the diversity of the collecting methods and the relatively small number of samples, the data collected from various types of gear other than rotenone could not be used to draw any definitive conclusions regarding the relative abundance and distribution of fishes throughout the Ohio River. Furthermore, they found that the great differences noted in the composition of the fish fauna were directly attributable to the limitations of the gear.

The lack of uniform fish data reporting procedures is generally well recognized by workers in this field and was anticipated by the study staff, since each fishery researcher usually samples a population with a particular goal in mind. Consequently, the results obtained and reported vary according to specific management and research objectives. For instance, if a researcher is studying the life history of a particular species, he may capture a number of other fish species but will not document them in his report. In another case, a biologist will include a list of fish species present in the water body he has sampled but will document the quantities of only those that are of commercial or sport value. Also, as pointed out previously, the reason that only certain species are documented in a report can be attributed to the selectivity of the sampling gear used. To further complicate the problem, routine reporting procedures, established within individual agencies, can often vary from time to time as the result of administrative or personnel changes.

Another problem encountered during the study was the definition of fish abundance, which Walburg (1969) defines as being proportional to catch divided by total effort if sampling is random and it is known that the fish are randomly distributed. However, because of the lack of knowledge on fish behavior and nonuniform environment these requirements are seldom attained. Consequently, the problem of documenting relative abundance of fish populations relies on the judgment of the individual investigator. For example, in studying the distribution of fishes in the Green River, Utah, after closure of Flaming Gorge Dam, Vanicek et al. (1970) arbitrarily classified relative abundance of each species as "rare", "uncommon", and "abundant", based on total numbers captured. Krumholz et al. (1962), in defining the relative abundance of fishes in the Ohio River, considered three separate ways in which this could be accomplished, namely: "(1) by the number of individuals of each species, (2) by the total weight of the individuals of each species, and (3) by the numbers and weights for each species taken each year". A comparison of the first two methods yielded differing species abundance. In the same study, the authors also tried to assess relative abundance by the frequency with which each species occurred in all collections. Their results showed that although the number of collections in which a species of fish was taken was not necessarily an indication of its relative abundance, it was a valuable aid in determining the ease of capture by a variety of methods.

The foregoing lack of standardized methods of equating fish abundance and the difficulty in correlating varied units of catch per unit of effort resulted in a computer storage category for this study called, "fish count". This is the sump into which all quantifying estimators of fish populations are stored.

It is apparent then, that any statistical inferences made from such numerics need to be cautious and qualified, and conclusions based on these will be superficial. In order to correct this frailty in the collected data, a correlation analysis would have to be performed to determine weighting factors or summing techniques which would yield meaningful fishery statistics.

In spite of the foregoing limitations of the data, the user of the fish-temperature data base can avoid or at least identify some of the statistical weaknesses of these data by proper use of the analytic capability built into the existing computer programs. These programs are modular in construction and facilitate the step-by-step evaluation of the data in the generation of a final composite temperature profile or a distributional plot of fish species through time. For instance, the "ALLPOSS" program presents the types of data available at each station location. After screening the stations for types of data, the program can be used to determine how much (frequency of occurrence) of the data is available at each station.

Program "STWKLY" calculates station temperature distributions on a weekly basis (using daily and weekly data) and lists all of the fish species sampled at the station for selected calendar periods of interest. At this point, the user has much of the information needed to select those stations for further analysis that assure a high correlation of dependent variables (fish and temperature statistics). If desired, the output of the programs STUDY1 and STWKLY can be plotted to assist visualization of the data before proceeding with composite or summary graphics which are described in this report.

Also at this point, additional reference information from the special events coding series and the fish-temperature documents catalogued for each station will also allow additional flexibility to the user in analyzing questionable results from the data base.

CRITIQUE

A number of generalizations can be drawn from this study about data quality, the state of the environment, and fish populations being sampled, and the way in which the fishery biology research and management community performed its work. The fish population data were generally poor and highly selective in all areas studied. Atlantic coast states had the poorest documentary record, followed by the Lower Mississippi Valley and Great Plains states. The best fish population data were found in the Far West and Great Lakes regions. Few states have Conservation or Fish and Game Departments or Commissions that maintain adequate programs to monitor changes in fish populations on a regular basis; many states have no organized programs at all. Federal government agency laboratories and field station reports varied widely, reflecting the interests and prerogatives of the local directors.

Virtually all environments accounted for in this study reflect the impact of man's activities on environmental quality to some degree ranging from moderate to severe. Engineering works such as dams, reservoirs, water diversions, navigation locks, stream channelization, highway construction, power plants, industrial plants, and wastewater treatment plants have all had major impacts on water flow characteristics, water volume, water quality, and habitat quality. No major fresh water resources remain that are relatively undisturbed; those that do are now impacted very heavily by the recreation and sport angling communities, and fish population structure is being altered either by design or circumstance, or both. There is no adequate pre-exploitation and development fish population reference baseline anywhere in the lower 48 states.

The quality of work performed by the fishery research and management community reveals major deficiencies on a national level. A general guild/craft philosophy prevails which allows the research and management community nearly unrestricted latitude in the way field work is performed, and in the manner in which data are collected, summarized, and reported. As a whole the community is a poor chronicle, the records reveal no basic standards for collection of fish population samples or their analysis; and such collections that do exist lack one or more of the essential categories of information on species identity, length-frequency distribution, sex ratios, reproductive information including spawning data, age and growth data, and indices of species diversity. In short, the study team found the entire biological data record so deficient that few coherent records could be found that would permit the kind of thorough analysis and interpretation of changes that the state of the general science now permits. There were simply too many voids in the data base.

Physical measurements of water temperature varied widely. The instrumentation used consisted of hand-held thermometers (both mercury and alcohol-filled), maximum-minimum recording thermometers, continuous recording thermographs (some with capillary-tube temperature sensing elements); and mechanical bath thermographs and electronic temperature instruments for obtaining vertical profiles of streams, lakes, and reservoirs. The accuracy of such diverse equipment varied significantly, and systematic measurement errors could not be accounted for, because the majority of equipment used was uncalibrated. Few agencies and individuals took steps to assess the accuracy of water temperature measurements; the USGS and the Hanford, Washington facility of the Energy Resources Development Agency (now Department of Energy) are notable exceptions. In addition, the biological community revealed a widespread lack of awareness of the significant diurnal range of temperature that can be observed on a given summer day under low-flow conditions. Too few fish population sampling records contained more than one "spot" measurement, and too often, the time of day that the measurement was taken was not logged.

Biological and fisheries data deficiencies stem from two major sources: (1) the inherent selectivity of the fish sampling gear used, and (2) the absence of a standard methodology to record, summarize, and report the information. Gear selectivity is directly related to the size range of the species being sampled, and whether the species are predators, filter-feeders, open water, or bottom dwellers. Other variations are caused by habitat conditions including prevailing weather, chemical and physical properties of the water, and changes in these conditions with seasons of the year. The wide array of sampling equipment used in the United States is indicative of the complexity and difficulty of the problem.

Chemical sampling techniques using rotenone or other materials were recognized by many workers to be inadequate and highly selective of certain species. In particular, recovery of animals for censusing purposes was a major limitation. Total population census methods were not used in most regions, and generally were employed in small streams or ponds where water removal was practical. In general, confusion exists as to the comparability of census data collected by various kinds of gear. Insufficient work has been done to permit intercomparisons on a large scale.

Uniform fishery data reporting procedures are needed. Because of the great diversity of sampling gear and techniques used, knowledgeable fishery workers have attempted to deal with the problem by deriving statistics into manageable numerical units. Eighteen major classes of derived statistics were encountered in this study. Frequently, although resident fish populations were sampled, the reports summarized only the information pertinent to the one or two species that were the object of the study.

A major problem that appeared frequently dealt with assessments of relative abundance. In almost all cases, the assessment was judgemental, because the fishery worker could not assume his sampling techniques for the species could meet the basic assumptions of randomness. Few workers consequently have gone beyond making a simple estimate such as "rare", "common", or "abundant".

Water quality measurements were seldom taken at the time of population censuses although some measurements of oxygen levels, pH, and total alkalinity were recorded routinely by the more careful observers. Inasmuch as these measurements heretofore have required traditional "wet-chemistry" treatment and analysis in the laboratory after collection, these data have been overlooked because of their relative high cost and inconvenience. Nevertheless, advent of new sensor technology promises early release from these former constraints. The need to know water quality conditions at the time of sampling has become of great importance in proper assessment of census information.

As noted earlier, no practical standards exist for the taking and recording of essential information on fish populations in individual habitats. Likewise, no standards exist for the orderly analysis and reportings of findings. The establishment of the Denver Public Library Reference Service in 1965 reflects an attempt to fill this need by bringing together all Federal Aid Reports and other unpublished information. Whether or not selected portions of a particular study are approved for publication in a refereed journal or other publication medium, there remains the need to provide the original observational record to state and federal agencies for other purposes.

This study revealed a multiplicity of federal, state, and regional agencies having an interest in water resources, fisheries, and recreation. A substantial number of federal programs are involved, either directly or indirectly as bureaus under two departments (Interior, Commerce) and as independent agencies (Environmental Protection Agency, U.S. Army Corps of Engineers, Energy Resources Development Agency (now Department of Energy), Tennessee Valley Authority). The need to coordinate these activities and to reduce overlap and duplication of effort is obvious.

Coordination of programs at the national level should provide inducement for similar coordination at the state, regional, and local levels. River basin commissions, conservation agencies, water quality control agencies, and utility districts should pool their resources and information to provide better programs in the public interest. Participation of academic institutions and professional organizations should be invited and encouraged at all levels.

The value of baseline measurements (i.e., a series of standardized measurements made periodically through a length time interval) in demonstrating secular trends in fish populations, water, and habitat quality is emphasized in this study. Moreover, the critical impact of data voids, broken observational series, major changes in techniques all complicate after-the-fact analyses by individuals not involved in the original work. Routine publication of data without analytical interpretations and judgments based on factors associated with collection of these original data constitutes insufficient treatment by the worker. Lastly, failure to compile and analyze the data at periodic intervals prevents full utilization of the information at hand when long-term comparisons are needed.

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APPENDIX A

LIST OF FISH SPECIES

000	Unidentified fish	
001	White sturgeon	Acipenser transmontanus
002	Alewife	Alosa pseudoharengus
003	Gizzard shad	Dorosoma cepedianum
004	Threadfin shad	Dorosoma petenense
005	Lake whitefish	Coregonus clupeaformis
006	Pink salmon (humpback)	Oncorhynchus gorbuscha
007	Chum salmon (dog or fall)	Oncorhynchus keta
008	Coho salmon (silver)	Oncorhynchus kisutch
009	Sockeye salmon (red, blueback)	Oncorhynchus nerka
010	Chinook salmon (king)	Oncorhynchus tshawytscha
011	Mountain whitefish	Prosopium williamsoni
012	Cutthroat trout	Salmo clarki
013	Rainbow trout	Salmo gairdneri
014	Atlantic salmon	Salmo salar
015	Brown trout	Salmo trutta
016	Brook trout	Salvelinus fontinalis
017	Lake trout (mackinaw)	Salvelinus namaycush
018	Rainbow smelt (American)	Osmerus mordax
019	Chain pickerel	Esox niger
020	Northern pike	Esox lucius
021	Muskellunge	Esox masquinongy
022	Carp (European)	Cyprinus carpio
023	Fathead minnow	Pimephales promelas
024	Longnose sucker	Catostomus catostomus
025	White sucker	Catostomus commersoni
026	Smallmouth buffalo	Ictiobus bubalus
027	Bigmouth buffalo	Ictiobus cyprinellus
028	Black bullhead	Ictalurus melas
029	Yellow bullhead	Ictalurus natalis
030	Brown bullhead	Ictalurus nebulosus
031	Channel catfish	Ictalurus punctatus
032	White bass	Morone chrysops
033	Striped bass	Morone saxatilis
034	Green sunfish	Lepomis cyanellus
035	Bluegill	Lepomis macrochirus
036	Smallmouth bass	Micropterus dolomieui
037	Largemouth bass	Micropterus salmoides
038	White crappie	Pomoxis annularis
039	Black crappie	Pomoxis nigromaculatus
040	Yellow perch	Perca flavescens
041	Sauger	Stizostedion canadense
042	Walleye	Stizostedion vitreum vitreum
043	Freshwater drum	Aplodinotus grunniens
044	(Use no. 046)	
045	Kokanee salmon (Landlocked)	Oncorhynchus nerka
046	Steelhead trout	Salmo gairdneri
047	Bonytail	Gila elegans
048	Humpback chub	Gila cypha
049	Colorado squawfish	Ptychocheilus lucius
050	Speckled dace	Rhinichthys osculus

051	Flannelmouth sucker	Catostomus latipinnis
052	Bluehead sucker	Catostomus discobolus
053	Humpback sucker	Xyrauchen texanus
054	Mottled sculpin	Cottus bairdi
055	Utah chub	Gila atraria
056	Redside shiner (Col. redshiner)	Richardsonius balteatus
057	Creek chub	Semotilus atromaculatus
058	Unidentified trout	-----
059	Pacific lamprey	Entosphenus tridentatus
060	American shad	Alosa sapidissima
061	Tench	Tinca tinca
062	Oregon chub	Hybopsis crameri
063	Northern squawfish	Ptychocheilus oregonensis
064	Threespine stickleback	Gasterosteus aculeatus
065	Trout perch	Percopsis omiscomaycus
066	Bridgelip sucker	Catostomus columbianus
067	Blacknose dace	Rhinichthys atratulus
068	Chiselmouth	Acrocheilus alutaceus
069	Peamouth	Mylocheilus caurinus
070	Green sturgeon	Acipenser medirostris
071	Unidentified chub	-----
072	Unidentified sucker	-----
073	Unidentified bass	-----
074	Unidentified catfish	-----
075	Unidentified crappie	-----
076	Unidentified perch	-----
077	Unidentified dace	-----
078	Unidentified bullhead	-----
079	Goldfish	Carassius auratus
080	Tui chub	Gila bicolor
081	Sacramento perch	Archoplites interruptus
082	White catfish	Ictalurus catus
083	Tahoe sucker	Catostomus tahoensis
084	Burbot (Ling)	Lota lota
085	Mountain sucker	Catostomus platyrhynchus
086	Lahontan cutthroat trout	Salmo clarki henshawi
087	Kamloops trout	Salmo gairdneri kamloops
088	Lahontan redside	Richardsonius egregius
089	Eulachon	Thaleichthys pacificus
090	Mosquitofish	Gambusia affinis
091	Golden shiner	Notemigonus crysoleucas
092	Dolly Varden	Salvelinus malma
093	(Use no. 52)	
094	Largescale sucker	Catostomus macrocheilus
095	Longnose dace	Rhinichthys cataractae
096	Unidentified sculpin(cottid)	Cottus sp.
097	Unidentified squawfish	-----
098	Piute sculpin	Cottus beldingi
099	Hitch	Lavinia exilicauda
100	Red shiner	Notropis lutrensis

101	Utah sucker	Catostomus ardens
102	Yellow bass	Morone mississippiensis
103	Redear sunfish	Lepomis microlophus
104	Striped mullet	Mugil cephalus
105	Arctic grayling	Thymallus arcticus
106	Desert pupfish	Cyprinodon macularius
107	Sacramento squawfish	Ptychocheilus grandis
108	Warmouth	Lepomis gulosus
109	Flathead catfish (yellow)	Pylodictis olivaris
110	Unidentified shad	-----
111	Cui-ui	Chasmistes cujus
112	Columbia speckled dace	Rhinichthys nubilus nubilus*
113	Shovelnose sturgeon	Scaphirhynchus platorynchus
114	Lake herring (cisco)	Coregonus artedii
115	Emerald shiner	Notropis atherinoides
116	Lake sturgeon	Acipenser fulvescens
117	Pumpkinseed	Lepomis gibbosus
118	Mooneye	Hiodon tergisus
119	Bowfin	Amia calva
120	Brook stickleback	Culaea inconstans
121	Longnose gar	Lepisosteus osseus
122	Orangespotted sunfish	Lepomis humilis
123	Quillback	Carpiodes cyprinus
124	Unidentified	-----
125	Redfin shiner	Notropis umbratilis
126	Rock bass	Ambloplites rupestris
127	Spotted sunfish	Lepomis punctatus
128	Bluntnose minnow	Pimephales notatus
129	Starhead topminnow	Fundulus notti
130	Brook silverside	Labidesthes sicculus
131	Grass pickerel	Esox americanus vermiculatus
132	Lake chubsucker	Erimyzon sucetta
133	River carpsucker	Carpiodes carpio
134	Spotted gar	Lepisosteus oculatus
135	Unidentified shiner	-----
136	Striped shiner	Notropis chrysocephalus
137	Tadpole madtom	Noturus gyrinus
138	Golden redhorse	Moxostoma erythrurum
139	Bigmouth shiner	Notropis dorsalis
140	Blackstripe topminnow	Fundulus notatus
141	Unidentified carpsucker	-----
142	Bay anchovi	Anchoa mitchilli
143	American eel	Anguilla rostrata
144	White perch	Morone americana
145	Hogchoker	Trinectes maculatus
146	Fourspine stickleback	Apeltes quadracus
147	Naked goby	Gobiosoma bosci
148	Spot	Leiostomus xanthurus
149	Silver perch	Bairdiella chrysura
150	Blueback herring	Alosa aestivalis

151	Atlantic needlefish	Strongylura marina
152	Tidewater silverside	Menidia beryllina
153	Banded killifish	Fundulus diaphanus
154	Mummichog	Fundulus heteroclitus
155	Sheepshead minnow	Cyprinodon variegatus
156	Rainwater killifish	Lucania parva
157	Spottail shiner	Notropis hudsonius
158	Stoneroller	Campostoma anomalum
159	(Use no. 110)	
160	Unidentified chubsucker	-----
161	Shortnose gar	Lepisosteus platostomus
162	Spotted sucker	Minytrema melanops
163	Greater redhorse	Moxostoma valenciennesi
164	Goldeye	Hiodon alosoides
165	Silver redhorse	Moxostoma anisurum
166	Unidentified redhorse	-----
167	Unidentified sunfish	-----
168	Highfin carpsucker	Carpiodes velifer
169	River redhorse	Moxostoma carinatum
170	Shorthead redhorse (northern)	Moxostoma macrolepidotum
171	Iowa darter	Etheostoma exile
172	River darter	Percina shumardi
173	Logperch	Percina caprodes
174	Silver chub	Hybopsis storeriana
175	Silver lamprey	Ichthyomyzon unicuspis
176	Unidentified darter	-----
177	Unidentified buffalo	-----
178	Unidentified eel	-----
179	(Deleted-Ocean species)	
180	Banded pygmy sunfish	Elassoma zonatum
181	Johnny darter	Etheostoma nigrum
182	Hornyhead chub	Nocomis biguttatus
183	Common shiner	Notropis cornutus
184	Spotfin shiner	Notropis spilopterus
185	Sand shiner	Notropis stramineus
186	Skipjack herring	Alosa chrysochloris
187	Blue catfish	Ictalurus furcatus
188	Longear sunfish	Lepomis megalotis
189	Spotted bass	Micropterus punctulatus
190	Paddlefish	Polyodon spathula
191	Northern hogsucker	Hypentelium nigricans
192	Black Redhorse	Moxostoma duquesnei
193	(Use no. 114)	
194	Redbreast sunfish	Lepomis auritus
195	Fallfish	Semotilus corporalis
196	Round whitefish	Prosopium cylindraceum
197	Creek chubsucker	Erimyzon oblongus
198	Swamp darter	Etheostoma fusiforme
199	Unidentified stickleback	-----
200	Golden trout	Salmo aquabonita

201	Pirate perch	Aphredoderus sayanus
202	Unidentified madtom	-----
203	Redfin pickerel	Esox americanus americanus
204	Blacktail redhorse	Moxostoma poecilurum
205	Speckled madtom	Noturus leptacanthus
206	Silvery minnow	Hybognathus nuchalis
207	Blacktail shiner	Notropis venustus
208	Redeye chub	Harperi hybopsis
209	Brindled madtom	Noturus miurus
210	Bullhead minnow	Pimephales vigilax
211	Atlantic croaker	Micropogon undulatus
212	Sharpfin chubsucker	Erimyzon tenuis
213	Southern flounder	Paralichthys lethostigma
214	Bigeye chub	Hybopsis amblops
215	Pugnose minnow	Notropis emiliae
216	Naked sand darter	Ammocrypta beani
217	Blackspotted topminnow	Fundulus olivaceus
218	Longnose shiner	Notropis longirostris
219	Bluehead chub	Nocomis leptocephalus
220	Atlantic sturgeon	Acipenser oxyrhynchus
221	Unidentified pickerel	-----
222	Flier	Centrarchus macropterus
223	Blue sucker	Cycleptus elongatus
224	Unidentified peanose	-----
225	Unidentified whitefish	-----
226	Banded sculpin	Cottus carolinae
227	Ozark minnow	Dionda nubila
228	Whitetail shiner	Notropis galacturus
229	Bleeding shiner	Notropis zonatus
230	Orangethroat darter	Etheostoma spectabile
231	Northern studfish	Fundulus catenatus
232	Slender madtom	Noturus exilis
233	Flat bullhead	Ictalurus platycephalus
234	Alabama shad	Alosa alabamae
235	Unidentified gar	-----
236	Unidentified sturgeon	-----
237	Mountain mullet	Agonostomus monticola
238	Unidentified needlefish	-----
239	Redeye bass	Micropterus coosae
240	Blackbanded darter	Percina nigrofasciata
241	Weed shiner	Notropis texanus
242	Bluestripe shiner	Notropis callitaenia
243	Taillight shiner	Notropis maculatus
244	Unidentified mullet	-----
245	Florida gar	Lepisosteus platyrhincus
246	Dollar sunfish	Lepomis marginatus
247	Seminole killifish	Fundulus seminolis
248	Bluespotted sunfish	Enneacanthus gloriosus
249	Unidentified gambusia	-----
250	Bluefin killifish	Lucania goodei

251	Tarpon	Megalops atlantica
252	Blackchin mouthbrooder	Tilapia melanotheron
253	Unidentified silverside	-----
254	Plains minnow	Hybognathus placitus
255	Black buffalo	Ictiobus niger
256	(Use no. 109)	
*257	Eel	Anguilla bostoniensis
258	Suckermouth redhorse	Moxostoma pappillosum
*259	Herring	Pomolobus pseudoharengus
*260	Madtom	Schilbsodes marginatus
261	(Deleted-Ocean species)	
262	Satinfin shiner	Notropis analostanus
263	Bluntnose shiner	Notropis simus
264	Plains killifish	Fundulus kansae
265	Speckled chub	Hybopsis aestivalis
266	Flathead chub	Hybopsis gracilis
267	River shiner	Notropis blennius
268	Suckermouth minnow	Phenacobius mirabilis
269	Arkansas River shiner	Notropis girardi
270	Mississippi silverside	Menidia audens
271	Stonecat	Noturus flavus
272	Alligator gar	Lepisosteus spatula
273	Rio Grande perch	Cichlasoma cyanoguttatum
274	(Use no. 215)	
275	Sailfin molly	Poecilia latipinna
276	Mexican tetra	Astyanax mexicanus
**277	Central weed shiner	Notropis roseus
278	Amazon molly	Poecilia formosa
**279	Rio Grande tetra	Astyanax fasciatus
280	Texas shiner	Notropis amabilis
281	Rio Grande shiner	Notropis jemezanus
282	Proserpine shiner	Notorpis proserpinus
283	Tamaulipas shiner	Notropis braytoni
284	Roanoke bass	Ambloplites cavifrons
285	Ladyfish	Elops saurus
286	Fountain darter	Etheostoma fonticola
287	Pinfish	Lagodon rhomboides
288	Blackbanded sunfish	Enneacanthus chaetodon
289	Mud sunfish	Acantharchus pomotis
290	Margined madtom	Noturus insignis
291	Sharpnose shiner	Notropis oxyrhynchus
**292	Brazos River shiner	Notropis brazosensis
293	Mimic shiner	Notropis volucellus
294	Gray redhorse	Moxostoma congestum
295	Banded sunfish	Enneacanthus obesus
296	(Deleted-Ocean species)	
297	Guadalupe bass	Micropterus treculi
298	Hickory shad	Alosa mediocris
299	Red drum	Sciaenops ocellata
300	Greenthroat darter	Etheostoma lepidum

301	Ribbon shiner	Notropis fumeus
302	Blackspot shiner	Notropis atrocaudalis
303	Scaly sand darter	Ammocrypta vivax
304	Slough darter	Etheostoma gracile
305	(Use no. 125)	
306	Golden topminnow	Fundulus chrysotus
307	Pallid shiner	Notropis amnis
** 308	Plains orangethroat darter	Poecilicthys spectabilis
309	Finescale dace	Phoxinus neogaeus
** 310	Southern sand shiner	Notropis deliciosus
311	Coastal shiner	Notropis petersoni
312	Fantail darter	Etheostoma
313	Unidentified hogsucker	-----
314	Arctic char	Salvelinus alpinus
315	Alaska blackfish	Dallia pectoralis
316	Unidentified salmon	-----
317	Sea catfish	Arius felis
318	Chestnut lamprey	Icthyomyzon castaneus
319	Cypress minnow	Hybognathus hayi
320	Pallid sturgeon	Scaphirhynchus albus
321	Sturgeon chub	Hybopsis gelida
322	Silverband shiner	Notropis shumardi
323	Central mudminnow	Umbra limi
234	Ninespine stickleback	Pungitius pungitius
325	Unidentified carp	-----
326	Southern brook lamprey	Ichthyomyzon gagei
327	Sabine shiner	Notropis sabinae
328	Black madtom	Noturus funebris
329	Freckled madtom	Noturus nocturnus
330	Bluntnose darter	Etheostoma chlorosomum
331	Cypress darter	Etheostoma proeliare
332	Blackside darter	Percina maculata
333	Dusky darter	Percina sciera
334	Unidentified herring	-----
335	Unidentified drum	-----
336	Swallowtail shiner	Notropis procne
337	Bridle shiner	Notropis bifrenatus
338	Cutlips minnow	Exoglossum maxillingua
339	Carolina madtom	Noturus furiosus
340	Steelcolor shiner	Notropis whipplei
341	Rainbow darter	Etheostoma caeruleum
342	Banded darter	Etheostoma zonale
343	Greenside darter	Etheostoma blennioides
344	Silver shiner	Notropis photogenis
345	Bigeye shiner	Notropis boops
346	River chub	Nocomis micropogon
347	Silverjaw minnow	Ericymba buccata
348	Rosyface shiner	Notropis rubellus
349	Channel darter	Percina copelandi
350	Slenderhead darter	Percina phoxocephala

351	Rosefin shiner	Notropis ardens
352	Shield darter	Percina peltata
353	Comely shiner	Notropis amoenus
354	Sea lamprey	Petromyzon marinus
355	Unidentified studfish	-----
356	Blacknose shiner	Notropis heterolepis
357	Blackchin shiner	Notropis heterodon
358	Sheepshead	Archosargus probatocephalus
359	Ghost shiner	Notropis buchanani
360	Harlequin darter	Etheostoma histrio
361	Western sand darter	Ammocrypta clara

* Not as in A list of common and scientific names of fishes from the United States and Canada, Amer. Fish. Soc., Special Publication No. 6, Third Edition, 1970.

** Not in A list of common and scientific names of fishes from the United States and Canada, Amer. Fish. Soc., Special Publication No. 6, Third Edition, 1970.

APPENDIX B

DATA ENCODING FORMATS

I FORMAT - LOCATION/GENERAL INFORMATION

Column(s)

1 "I" letter designator

2-7 Station number: The first two digits represent state designator as taken from STORET state code numbers. The remaining four digits comprise an arbitrary serial number of stations within that state and are normally assigned in units of 100.

Example: |03|0100| = Arizona, Lake Mohave at Boulder

If several stations are located on the same body of water and are in close proximity to each other, the serial numbers assigned differ only in the last two digits to reflect this degree of commonality.

Example: |03|0101| = Arizona, Lake Mohave - Davis Dam

8-10 County code Taken from USGS "Catalog of Information on Water Data, Index to Water Quality Section,"

11 Type of water body

1. Lake
2. River
3. Stream
4. Reservoir
5. Other (e.g., swamp, bayou, marsh, etc.)

12 Thermal characteristics of body of water

1. Stratified
2. Isothermal
3. Not given

13-14 Major river basin in which this station is located: Taken from EPA designation (Appendix G 3).

15-16 Minor river basin in which this station is located: Taken from EPA designation (Appendix G 3).

17-22 Northern latitude of station location: Degree, minutes, seconds (no decimals)

23-29 West longitude of station location: Degree, minutes, seconds (no decimals)

Column(s)

30 Precision code -- an estimate of the accuracy of latitude and longitude designation

1. (not to be used)
2. within 1.0"
3. within 10.0"
4. within 30.0"
5. within 1.0'
6. within 10.0'
7. within 30.0'
8. within 1°

31 Average isotherm of surface water temperature

1. < 40
2. 40-44
3. 45-49
4. 50-54
5. 55-59
6. 60-64
7. 65-69
8. > 69

Taken from the USGS Hydrologic Investigations Atlas HA-235, "Temperature of Surface Waters in the Conterminous United States."

32-36 Elevation of studied area in feet (blank if unknown; zero designates zero elevation)

37 Category of nearest major landmark to station location

1. City, state
2. Town
3. Highway
4. River mile
5. Other (e.g., physical features)

38-80 The name of nearest landmark as designated in Column 37.

J FORMAT - BIBLIOGRAPHICAL AND/OR EDITORIAL REFERENCE

Column(s)

1 "J" letter designator

2-7 Station number as described on "I" format

8 Serial number: Up to nine J-format records are allowed for listing of all accession numbers applicable to a given station location.

9-14 Blank

15-20 Accession number

25-30 Accession number

35-40 Accession number

45-50 Accession number

55-60 Accession number

Column(s)	
65-70	Accession number
75-80	Accession number

A six-digit accession number, ranging from 000,001 through 899,999 was assigned to all documents containing fish-temperature data or ancillary information used in this study. The inclusion of these numbers allows the user to retrieve original data documents for each station defined in the data base.

Accession numbers 900,000 through 999,999 were used to reference physical or functional changes in the environment which would affect the use or interpretation of the encoded numbers.

K FORMAT - STATION NAME

Column(s)	
1	"K" letter desingator
2-7	Station number
8-80	Station name and state - completely written out

T FORMAT - DAILY TEMPERATURE

Column(s)	
1	"T" letter designator
2-7	Station number
8-9	Year (no blanks or zero)
10-11	Month (no blanks or zero)
12	Temperature identification: 1 Daily
13	Temperature type: 1 Minimum 2 Maximum 3 Average minimum 4 Average maximum 5 Discrete 6 Average
14	Sampling equipment: 0 Not given 1 Taylor thermometer 2 Ryan thermometer 3 Electric recording 4 Pocket thermometer 5 Tempscribe temperature recorder 6 Palmer temperature recorder 7 Oxygen temperature meter 8 Telethermometer 9 USGS Tape Library

Column(s)

15 Depth/Degree units (no blanks):

1 Feet and °F
2 Feet and °C
3 Meters and °F
4 Meters and °C

16-18 Depth at which water temperatures were taken (no blanks -- use zero if surface; -1 if unknown)

Example:

16	17	18
	-	1

19-80 31 Daily temperatures (Leave blank if temperature is not given; use zero if temperature is zero.) Two columns allowed for each temperature.

Example:

Column	19	20	21	22	..	..	..	..	79	80
Temperature	4	0	3	9					4	1

T FORMAT - WEEKLY, MONTHLY, QUARTERLY, SEASONAL AND ANNUAL TEMPERATURES

Column(s)

1 "T" letter designator

2-7 Station number

8-9 Year (no blanks--use data of observation or first year of several years of averaged data--see column 17-18)

10 Temperature identification:

1 Daily
2 Weekly
3 Monthly
4 Quarterly
5 Seasonal
6 Annual

11 Temperature type:

1 Minimum
2 Maximum
3 Average minimum
4 Average maximum
5 Discrete
6 Average

12 Sampling equipment:

0 Not given
1 Taylor thermometer
2 Ryan thermometer
3 Electric recording
4 Pocket thermometer
5 Tempscribe temperature recorder
6 Palmer temperature recorder
7 Oxygen temperature meter
8 Telethermometer
9 USGS Tape Library

13 Depth/Degree units (no blanks)

1 Feet and °F
2 Feet and °C
3 Meters and °F
4 Meters and °C

Column(s)	
14-16	Depth at which water temperatures were taken (no blanks--use zero if surface; -1 if unknown)
17-18	Number of years (maximum of 30) of accumulated or averaged data, starting with the year written in column 8-9. (Leave blank or use 1 if one year only.)

	WEEKLY	MONTHLY	QUARTERLY	SEASONAL	ANNUAL
19-20	**	Blank	Blank	Blank	Blank
21-22	Week 1*	Jan*	1st Quarter*	Spring*	1st Year*
23-24	Week 2*	Feb*	2nd Quarter*	Summer*	2nd Year*
25-26	Week 3*	Mar*	3rd Quarter*	Fall*	3rd Year*
27-28	Week 4*	Apr*	4th Quarter*	Winter*	4th Year*
29-30	Week 5*	May*	(-----no more data-----)		5th Year*
31-32	etc.	etc.			etc.
etc. to 79-80	(up to 26 weeks per entry)				(up to 30 years)

* Leave blanks for period of no data

** In the case of weekly data, there is room on the format for only 26 observations. The data recorded could be for week 1, week 2, etc., through week 26, or for week 27, week 28, etc., through week 52. In the first case, "01" is entered in column 19-20 and in the second case, "27" is entered in 19-20 to indicate which of the two possible groups of weekly data is being encoded.

F FORMAT - FISH COUNTS AND GENERAL INFORMATION

Column(s)	
1	"F" letter designator
2-7	Station number
8-9	Year (no blanks--use date of observation or publication)
10-11	Month (no blanks--use zero if unknown, 13 if annual data)
12-13	Day (may be blank)
14-16	Species (three-digit numeric referring to specific species, see Appendix H)
17-27	Fish quantity indicator
28-30	Sampling depth (-1 if not given)
31	Depth units (no blanks) 1 Feet 2 Meters 3 Not given

Column(s)

32-33 Sampling method

01 Electro
02 Gill net
03 Weir
04 Creel
05 Poison
06 Ladder
07 Seine
08 Trap
09 Stream diversion
10 Trap net
11 Trawl
12 Fyke net
13 Natural kill
14 Combination
15 Tow net
16 Meter net
17 Hoop net
18 Trammel net
19 Not given
20 Trot line
21 Unknown netting

34 Fish condition (defined as general health of fish)

1 Good
2 Not good
3 Not given

35 Fish development

1 Normal
2 Stunted
3 Not given

36-38 Not used

39-40 Alpha code

41-45 Count for above

46-47 Alpha code

48-52 Count for above

53-54 Alpha code

55-59 Count for above

60-61 Alpha code

62-66 Count for above

67-68 Alpha code

69-73 Count for above

74-75 Alpha code

76-80 Count for above

B FORMAT - SPAWNING DATA

Column(s)	
1	"B" letter designator
2-7	Station number
8-9	Year (no blanks--use date of observation or date of publication)
10-11	Month (no blanks--use zero if unknown, 13 if annual data)
12-13	Day (no blanks--use zero if unknown)
14-16	Species number
17	Residency: 1 Transient 2 Permanent
18-25	Period of transient occupation--from month/day to month/day
26	Recruitment: 1 Native 2 Stocked 3 Introduced 4 Native and stocked 5 Stocked and introduced 6 Not given
27	Spawning: 1 Induced 2 Natural 3 Both 4 None 5 Not given
28-35	Spawning dates--from month/day to month/day
36	Spawning success 1 Good 2 Poor 3 Not given
37-38	Not used
39-40	Alpha code
41-45	Count for above
46-47	Alpha code
48-52	Count for above
53-54	Alpha code

Column(s)	
55-59	Count for above
60-61	Alpha code
62-66	Count for above
67-68	Alpha code
69-73	Count for above
74-75	Alpha code
76-80	Count for above

APPENDIX C

FISHERIES-TEMPERATURE STATIONS COMPLETED

ALABAMA

*010000	State of Alabama
#010100	Wheeler Reservoir Browns Ferry Plant at River Mile 284
#010101	Wheeler Reservoir Browns Ferry Plant at River Mile 293
#010102	Wheeler Reservoir Browns Ferry Plant at River Mile 299
*010200	Tennessee River below Guntersville Dam

ALASKA

*020000	State of Alaska
020100	Sashin Creek on Little Port Walter Bay, Baranof Island
020200	Maybeso Creek, Prince of Wales Island
020300	Harris River, Prince of Wales Island
020400	Indian Creek, Prince of Wales Island
020500	Cottonwood Creek at Outlet Weir
020501	Cottonwood Creek at Inlet Weir
020600	Wasilla Lake
020700	Eva Creek, Baranof Island
020800	Hood Bay Creek, Admirality Island
020900	Bear Creek, Kenai Peninsula
#021000	Ship Creek near Anchorage
021100	Campbell Creek near Anchorage
021200	Our Creek near Glenallen
021300	Gulkana Lake
021400	Summit Lake
021500	Russian River, Kenai Peninsula
021600	Swanson River, Kenai Peninsula
021700	East Finger Lake, Kenai Peninsula
021800	Kvickak River near Igiugig
021900	Fire Creek Weir below Upper Fire Lake
022000	Fire Creek Weir below Lower Fire Lake
022100	Anchor River, Kenai Peninsula
022101	South Fork Anchor River, Kenai Peninsula
022200	Deep Creek, Kenai, Kenai Peninsula
022300	Ninilchik River, Kenai Peninsula
022400	Stariski Creek, Kenai Peninsula
022500	Quartz Creek, Kenai Peninsula
022600	Cresent Creek, Kenai Peninsula
022700	Cooper Creek, Kenai Peninsula
022800	Hidden Lake, Kenai Peninsula
022900	Big Lake
023000	Lake Louise

ARIZONA

*030000	State of Arizona
030100	Lake Mohave-Boulder
030101	Lake Mohave-Davis Dam
030200	Salt River
030300	Parker Canyon Lake
030400	Imperial Reservoir
030500	Long Lake

ARKANSAS

*040100	Bull Shoals Reservoir
040300	Lake Hamilton
040400	Lake Catherine
#040401	Lake Catherine, Steam Plant Bay
040500	Lake Ouachita
040600	Little Red River near Pangburn
040601	Little Red River near West Point
040700	Mississippi River at Helena
*040800	White River
040900	Mississippi River in State of Arkansas
*041000	Beaver Reservoir on White River

CALIFORNIA

*050000	State of California
050100	Nimbus Hatchery on the American River
050200	Trinity River at Lewiston Fish Trapping Facilities
050300	Iron Gate Hatchery on the Klamath River
050400	Castle Lake
050500	Lake Pillsbury
050600	Sagehen Creek
050700	Feather River Hatchery
050800	Lake Crowley
050900	Lake Havasu
051000	Shasta River
051200	Klamath River
051300	Lake Tahoe
*051500	Sacramento River
*051900	Clear Lake
052000	Pine Flat Lake
*052300	Eagle Lake
052700	Sacramento River near Red Bluff
*052800	Trinity River

COLORADO

*070000	State of Colorado
070100	Forest Lake
070300	Trappers Lake
070400	Two Buttes Reservoir
070500	Skaguay Reservoir
070501	West Beaver Creek, Inlet Stream to Skaguay Reservoir
070600	Carbody Lake
070700	Barbour Lake
070800	Boyd Lake
*070900	Forest Canyon

CONNECTICUT

*080000	State of Connecticut
080100	Enfield Dam on the Connecticut River
*080200	West Hill Pond
*080300	Lower Connecticut River

DELEWARE

DISTRICT OF COLUMBIA

*100000	District of Columbia

FLORIDA

*110000	State of Florida
110100	St. Johns River
110200	Apalachicola River at Jim Woodruff Dam
110300	Newnans Lake
110400	Lake Apopka
110500	Deer Point Lake
110600	Lake Griffin
110700	Lake Harris
110800	Lake Hollingsworth
110900	Lake Parker
111000	Lake Trafford
111100	Dead Lake
111200	Lake Hunter
*111300	Everglades
*111400	Lake Panasoffkee
*111500	Lake Weir

GEORGIA

IDAHO

*150000	State of Idaho
150100	Arrowrock Reservoir
150200	Cascade Reservoir
150300	Anderson Ranch Reservoir
150400	Clearwater River
150500	North Fork Clearwater River
150600	Lemhi Big Springs Creek
150700	Lake Pend Oreille
*150800	Preist Lakes
150900	Lemhi River at River Mile 28.8

ILLINOIS

*160000	State of Illinois
160100	Lake Le-Aqua-na
160200	Argyle Lake
160300	Red Hills Lake
160400	Ramsey Lake
160500	Lincoln Trail Lake
160600	Lake Murphysboro
160700	Beaver Dam Lake
160800	Siloam Springs Lake
160900	Spring Lake
*161000	Fork Lake
*161100	Park Pond
161200	Mississippi River, Pool 18, From New Boston, IL to above Burlington, IA
161201	Mississippi River, Pool 26, From Winfield, MO to Alton, IL
161202	Mississippi River in State of Illinois
161203	Mississippi River, Pool 26B, From St. Louis, MO to Caruthersville, MO
161204	Mississippi River at Chester, IL
161205	Mississippi River at Quincy, IL
161206	Mississippi River at Moline, IL
161207	Mississippi River at Alton, IL
*161300	Embarras River
*161400	Dismal Creek
*161500	Kaskaskia River

INDIANA

IOWA

*180000	State of Iowa
*180100	Clear Lake
*180200	Manchester
*180300	Des Moines River
180400	Mississippi River, Pool 10, From Harpers Ferry, IA to Guttenberg, IA
180401	Mississippi River, Pool 12, From Dubuque, IA to Bellevue, IA
180402	Mississippi River, Pool 13, From Bellevue, IA to above Clinton, IA
180403	Mississippi River, Pool 14, From Clinton, IA to La Claire, IA
180404	Mississippi River, Pool 15, From La Claire, IA to Davenport, IA
180405	Mississippi River, Pool 16, From Rock Island, IL to Muscatine, IA
180406	Mississippi River, Pool 17, From Muscatine, IA to New Boston, IL
180407	Mississippi River, Pool 19, From Burlington, IA to Keokuk, IA
180500	Mississippi River in State of Iowa
180600	Mississippi River at Dubuque, IA

KANSAS

*190000	State of Kansas
190100	McKinley Lake
190200	Chase County State Lake
190400	Montgomery County State Lake
190500	John Redmond Reservoir
190600	McPherson County State Lake
190700	Meade County State Lake
190800	Atchison County State Lake
190900	Milford Reservoir
191000	Tuttle Creek Reservoir
191100	Douglas County State Lake
191200	Kansas River at Wamego
*191300	Smoky Hill River
191400	Cherokee County Lake No. 1
191500	Cherokee County Lake No. 3
191600	Norton Reservoir
*191700	Junction of Neosho and Cottonwood Rivers

KENTUCKY

200100	Barren River Reservoir
200200	Nolan River Reservoir
200300	Mississippi River at Hickman
200301	Mississippi River in State of Kentucky
200400	Licking River near Butler
200401	Licking River near Kentontown
200402	Licking River near Blue Lick Spring
200403	Licking River near West Liberty
200404	Licking River near Swampton
200500	So. Fork Licking River near Cynthiana
200600	So. Fork Elkhorn Creek near Faywood
200601	So. Fork Elkhorn Creek near Paynes
200700	No. Fork Elkhorn Creek near Georgetown
200800	Main Elkhorn Creek near Frankfort
*200900	Plum Creek
*201000	Doe Run

LOUISIANA

210100	Mississippi River at Tarbert Landing
210101	Mississippi River at Luling
210200	Atchafalaya River at Simmesport
210300	D'Arbonne Lake
210400	Spring Bayou

210500	Amite River
210600	Six Mile Creek
210700	Lac Des Allemands
210800	Sabine River, Station 1B
210801	Sabine River, Station 2B
210802	Sabine River, Station 3B
210803	Sabine River, Station 1A
210804	Sabine River, Station 2A
210805	Sabine River, Station 3A
210806	Sabine River, Station 4A
210807	Sabine River, Station 5A
210808	Sabine River, Station 6A
210809	Sabine River, Station 7A
210810	Sabine River, Station 8A
210811	Sabine River, Station 9A
210812	Sabine River, Station 10A
210813	Sabine River, Station 11A
210814	Sabine River, Station 12A
210900	Anacoco Lake
211000	Bundicks Lake
211100	Chicot Lake
211200	Henderson Lake
211300	Tchefuncte River
211400	Mississippi River in State of Louisiana

MAINE

*220000	State of Maine
220100	Moosehead Lake
220200	Barrows Stream
220300	Sebasicook Lake

MARYLAND

*230000	State of Maryland
230100	Patuxent River at Benedict Bridge
230200	Loch Raven Reservoir
230400	Savage River Reservoir
230500	Little Patuxent River
230600	Nanticoke River
230700	Choptank River
230800	Blackwater River
230900	Potomac River at Lander

MASSACHUSETTS

*240000	State of Massachusetts
240100	Connecticut River at Gill and Northfield areas
240101	Connecticut River at Montague, Gill, Greenfield, Deerfield areas
240102	Connecticut River at Sunderland, Deerfield, Whately areas
240103	Connecticut River at Hadley, Hatfield, Northampton areas
240104	Connecticut River at the Oxbow in Northampton
240105	Connecticut River at South Hadley, Holyoke, Chicopee areas
240106	Connecticut River at West Springfield, Springfield, Agawam, Longmeadow areas

MICHIGAN

*250000	State of Michigan
250100	Pigeon River Trout Research Station
*250200	Ostego Lake
*250300	Houghton Lake
*250400	Southern Lake Superior
250500	Hunt Creek Trout Research Station
250600	More Trout, Inc (MTI)
250700	Guiley Pond

MINNESOTA

*260000	State of Minnesota
#260100	St. Croix River at Allen S. King Generating Plant
#260101	St. Croix River at River Mile 21.5
#260102	St. Croix River at River Mile 20.7
#260103	St. Croix River at River Mile 20.6
#260104	St. Croix River at River Mile 19.2
#260105	St. Croix River at River Mile 17.8
#260106	St. Croix River at River Mile 17.3
#260200	Monticello Nuclear Generating Plant on Mississippi River at 1.1 River Miles
#260201	Mississippi River at 1.5 River Miles
#260202	Mississippi River at 1.2 River Miles
#260203	Mississippi River at 0.8 River Miles
#260204	Mississippi River at 1.0 River Miles
260300	Lake George
260301	Lake George Northern Pike Slough
*260400	Red Lake
260500	Mississippi River, Pool 2, From Minneapolis, MN to Hastings, MN
260501	Mississippi River, Pool 5A, From below Minneiska, MN to Goodview, MN
260502	Mississippi River, Pool 6, From above Winona, MN to Trempealeau, WI
260503	Mississippi River From Grand Rapids to Brainard, MN
260504	Mississippi River From Winnibigoshish to Grand Rapids, MN
260505	Mississippi River From Brainard to Elk River, MN
260600	Mississippi River in State of Minnesota
260700	Mississippi River at St. Paul, MN
260701	Mississippi River at Clearwater, MN
260702	Mississippi River at St. Cloud, MN
260703	Mississippi River at Sauk Rapids, MN
260704	Mississippi River at Royalton, MN
260705	Mississippi River at Camp Ripley, MN
260706	Mississippi River at Jacobson, MN
260707	Mississippi River at Grand Rapids, MN

MISSISSIPPI

270100	Wolf Lake
270200	Mossy Lake
270300	Little Tallahatchie River
270400	Coldwater River
270500	Ross R. Burnett Reservoir
270600	Bowie River 1.9 Miles above the mouth
270601	Bowie River 1.06 Miles above the mouth
270700	Leaf River 69.1 Miles above the mouth
270701	Leaf River 56.5 Miles above the mouth
270800	Tallahala Creek
270801	Tallahala Creek 9.5 Miles above the mouth
270900	Escatawpa River at River Mile 10.6
271000	Pascagoula River at River Mile 10.5
271100	Jordan River at Hwy. 603
271200	Big Biloxi River at Hwy. 49
271201	Big Biloxi River at Lorraine Crossing
271300	Little Biloxi River at Hwy. 49
271400	Mississippi River at Tunica
271401	Mississippi River at Vicksburg
271500	Mississippi River in State of Mississippi

MISSOURI

*280000	State of Missouri
280100	James River at Nelson Mill Bridge
280101	James River at Highway 14
280102	James River at Bernet Farm
280200	Wilson Creek at Manley Ford

*280300	Neosho
280400	Mississippi River, Pool 20, From Keokuk, IA to Canton, MO
280401	Mississippi River, Pool 21, From Canton, MO to Quincy, IL
280402	Mississippi River, Pool 22, From Quincy, IL to Saverton, MO
280403	Mississippi River, Pool 24, near Louisiana, MO
280404	Mississippi River, Pool 25, From Louisiana, MO to Winfield, MO
280500	Mississippi River in State of Missouri
280600	Mississippi River at St. Louis, MO

MONTANA

*290000	State of Montana
290100	Hungry Horse Reservoir
*290200	Flathead Lake
*290300	Thompson Lake
290400	Willow Creek Reservoir
*290500	Seeley Lake
*290600	Grebe Lake
*290700	North Fork of Flathead River

NEBRASKA

*300000	State of Nebraska
300100	North Platte River at Lewellen
300200	Lake McConaughy
300300	Missouri River at Fort Calhoun
300400	Missouri River at Brownville

NEVADA

*310000	State of Nevada
310400	Walker Lake
310500	Lake Tahoe
310600	Lake Mead at Temple Bar
310601	Lake Mead at Overton Dock
310602	Lake Mead at Echo Bay
310603	Lake Mead at Virgin Basin
310604	Lake Mead at Black Canyon
310605	Lake Mead at Las Vegas Wash
310606	Lake Mead at Boulder Basin (Callville Bay & Swallow Cove)
310607	Lake Mead at South Cove
310800	Bassett Lake
310900	Topaz Reservoir
311000	Adams-McGill Reservoir
311101	Mohave Lake near Willow Beach
311102	Mohave Lake near Eldorado Canyon
311103	Mohave Lake near Cottonwood Cove
311104	Mohave Lake near Katherine Landing
311200	Pyramid Lake
311300	Upper Truckee River
311301	Lower Truckee River
311400	Salmon Falls River
311401	South Fork Salmon Falls River
311402	North Fork Salmon Falls River
311500	Cleve Creek

NEW HAMPSHIRE

*320000	State of New Hampshire
320100	Swift River
320200	Upper Baker Pond
#320300	Merrimack River North of Merrimack Generating Plant
#320301	Merrimack River South of Merrimack Generating Plant
#320302	Merrimack River South of Hooksett Power Dam

NEW JERSEY

*330000	State of New Jersey
330100	Stations 26 and 25 on Big Flatbrook River
330101	Stations 21 and 20 on Big Flatbrook River
330102	Station 19 on Big Flatbrook River
330103	Stations 15, 14, and 13 on Big Flatbrook River
330104	Station 12-3 on Little Flatbrook River
330105	Station 12-6 on Little Flatbrook River
330106	Stations 12 and 11 on Big Flatbrook River
330107	Station 9 on Big Flatbrook River
330200	Deleware River at Trenton
330201	Deleware River at Belvidere

NEW MEXICO

340100	San Juan River
340200	Navajo Reservoir

NEW YORK

*350000	State of New York
*350100	Cayuge Lake
350400	Oneida Lake
*350500	Keuka Inlet
*350600	Catherine Creek
*350700	Grout Brook
*350800	Finger Lakes
350900	Raquette Lake
351000	Seneca Lake
351100	Blue Mountain Lake
351200	Chautauqua Lake
351300	Deleware River, East Branch
351301	Deleware River, West Branch
351302	Deleware River at Long Eddy
351303	Deleware River at Mongaup

NORTH CAROLINA

*360000	State of North Carolina
*360100	Lake Wylie
360200	Bones Creek
360300	Lake James
360400	Merchant's Mill Pond
360500	Lake Phelps
360600	Alligator Lake
360700	John Kerr Scott Reservoir
360800	Kinney Cameron Lake
361000	Chowan River at River Mile 55
361001	Chowan River at River Mile 48
361100	High Rock Lake
*361200	Waccamaw River
*361300	Lumber River
*361400	South River
361500	Lexington-Thomasville Reservoir
361600	Lake Fisher
361700	Lake Concord
361800	Lake Lexington
361900	Lake Lee
362000	Lake Monroe

NORTH DAKOTA

OHIO

*380000	State of Ohio
*380100	Lake Erie
*380200	Massie Creek

OKLAHOMA

*390000	State of Oklahoma
390100	Keystone Reservoir on Arkansas River
390300	Canton Reservoir
390400	Tenkiller Ferry Reservoir
390500	Lake Carl Blackwell
390600	Lake Hefner
390700	Mountain Fork River above Broken Bow Reservoir
390701	Mountain Fork River below Broken Bow Reservoir

OREGON

*400000	State of Oregon
400100	Rogue River Goldray Dam
400200	Willamette River near Oregon City
400300	Sandy River Marmot Dam
400400	Deschutes River at mouth
400500	North Umpqua River, Winchester Dam
400700	Thomas Creek
400800	Detroit Reservoir
400900	McKenzie River
401000	Breitenbush River
401100	South Fork McKenzie River
401200	North Santiam River
*401300	Lake of the Woods

PENNSYLVANIA

*410000	State of Pennsylvania
410100	Deleware River at Millanville
410101	Deleware River at Matamoras
410102	Deleware River at Minnisink Island
410103	Deleware River at Tocks Island
410104	Deleware River at Raubs Island
410105	Deleware River at Marshall Islands
410106	Deleware River at Scudders Falls

RHODE ISLAND

*430000	State of Rhode Island
*430100	Pausacaco Pond
*430200	Apponaug Brook

SOUTH CAROLINA

*450000	State of South Carolina
450100	Santee River near Jamestown
450101	Santee River near Wilson's Landing
450200	Cooper River near Lake Moultrie
450201	Cooper River near Charleston
450300	Edisto River
450400	Sawhatchie River
450500	Savannah River
450600	Ashepoo River

SOUTH DAKOTA

*460000	State of South Dakota
460100	Oahe Reservoir
*460200	Lewis and Clark Lake

TENNESSEE

*470000	State of Tennessee
*470100	Norris Reservoir
470200	Mississippi River in State of Tennessee
470201	Mississippi River at Memphis
470300	Tennessee River below Pickwick Dam
470401	Elk River from River Mile 41-53
470402	Elk River from River Mile 69-113
470403	Elk River from River Mile 124-163
470500	Obey River, Upper Dale Hallow Tailwater Zone
470501	Obey River, Middle Dale Hallow Tailwater Zone
470502	Obey River, Lower Dale Hallow Tailwater Zone
470600	Hurricane Creek below Hurricane Mills Dam
470601	Hurricane Creek at State Hwy 13
470602	Hurricane Creek at Long Wallace Bridge, County Road 6223
470700	Buffalo River at River Mile 17
470701	Buffalo River at River Mile 58
470800	Duck River
*470900	Dale Hallow Reservoir
*471000	Center Hill Reservoir

TEXAS

*480000	State of Texas
480100	Lake Texoma
480101	Buncombe Creek Arm-Lake Texoma
480200	Lake Corpus Christie
480300	Falcon Reservoir
480400	Lake Bentsen
480500	Delta Orchards Lake
480600	Olmito Lake
480700	Casa Blanca Lake
480800	Nueces River below Lake Corpus Christi
480900	Frio River
*481000	Lake Diversion
481100	Buchanan Lake
481200	Lake Inks
481300	Lake Travis
481400	Murvaul Bayou Reservoir
#481500	Striker Creek Reservoir
481600	Lake Whitney
481700	Possum Kingdom Lake
481800	Lake Granbury
481900	San Angelo Reservoir
*482000	Ferndale Club Lake
#*482100	Lake Colorado City
482200	Colorado River near Bastrop
482201	Colorado River near La Grange
482202	Colorado River near Columbus
482203	Colorado River near Altair
482204	Colorado River near Wharton
482205	Colorado River near Bay City

UTAH

*490000	State of Utah
490100	Upper Green River
490101	Lower Green River
490200	Flaming Gorge Reservoir
490300	Utah Lake
490400	Glen Canyon Reservoir (Lake Powell)
490401	Glen Canyon Reservoir (Lake Powell)
*490500	Logan River
*490600	Green River

VERMONT

*500000	State of Vermont
500100	Lake Champlain
*500200	Pittsford

VIRGINIA

*510000	State of Virginia
*510100	York River

WASHINGTON

*540100	Columbia River
540101	Columbia River, Bonneville Dam
540102	Columbia River, The Dalles Dam
540103	Columbia River, John Day Dam
540104	Columbia River, McNary Dam
540105	Snake River, Ice Harbor Dam
540106	Snake River, Lower Monumental Dam
540112	Priest Rapids Dam
540200	Silver Lake
540300	Goodwin Lake
540400	Shoecraft Lake

WEST VIRGINIA

*550000	State of West Virginia
550100	Sutton Reservoir
550200	Summerville Reservoir
550300	Middle Island Creek
550400	Castlemans Run Lake
550500	Burches Run Lake
550600	Conaway Run Lake
550700	New Creek Lake
550800	Warden Lake
550900	Sleepy Creek Lake
551000	Doe Run Lake
551100	Bear Lake
551200	Teter Creek Lake
551300	Baker Lake
551400	Laurel Lake
551500	Bonds Creek Lake

WISCONSIN

*560000	State of Wisconsin
560200	Lake Winnebago
560300	Lawrence Creek
560400	Lake Winnie Connie
560500	Lake Butte Des Morts
560600	Wolf River at New London

560601	Wolf River st Spoehr's Marsh
560700	Lake Poygon
560800	Fox River, Marshes
560900	Cox Hallow Lake
561000	Murphy Flowage Reservoir
*561100	Brule River
561200	Escanaba Lake
561300	Gilbert Lake
561400	Bohemian Valley Creek
*561500	University of Wisconsin Garden Ponds
*561600	Lake Mendota
*561700	Trout Lake
*561800	Muskellunge Lake
*561900	Green Lake
562000	Mississippi River, Pool 3, From Hastings, MN to above Red Wing, MN
562001	Mississippi River, Pool 4, From Red Wing, MN to Alma, WI
562002	Mississippi River, Pool 4A, Lake Pepin
562003	Mississippi River, Pool 5, From Alma, WI to below Minneiska, MN
562004	Mississippi River, Pool 7, From Trempealeau, WI to above La Crosse, WI
562005	Mississippi River, Pool 8, From La Crosse, WI to Genoa, WI
562006	Mississippi River, Pool 9, From Genoa, WI to below Lynxville, WI
562007	Mississippi River, Pool 11, From Guttenberg, IA to Dubuque, IA
563000	Mississippi River in State of Wisconsin

WYOMING

*570000	State of Wyoming
570100	Fontenelle Reservoir
570200	Green River below Fontenelle
570201	Green River above Flaming Gorge
570300	Ocean Lake
570400	Torrey Creek
*570500	Arnica Lake, Yellowstone
*570600	Yellowstone Lake

* Spawning Data only.
# Power Plant.

APPENDIX D

SPECIAL DATA CODES

In order to facilitate the usefulness and user understanding of the fish-temperature data base, special information codes have been incorporated into the station data files. These codes are presented and discussed in the following paragraphs.

ALPHA CODES

In reviewing the material gathered for the fish-temperature survey a potential was recognized for the inclusion in the data base of additional data above and beyond that required by the present study. It was felt that by means of such information subsequent users of the data would have greater flexibility in manipulating data retrieved. Thus, the user would know not only at what temperatures a particular species was found, but would also know other parameters such as the rate at which the fish were caught, the sampling size of each catch, migration and emigration information, spawning data, etc. In order to assimilate this additional numerical data within the structure of the fish-temperature survey without unduly complicating the encoding forms, a special code was devised that could be enlarged to accommodate any data situation.

This alpha-numeric code, called the Alpha Code, consists of two alphabetic symbols followed by five numeric digits. The first letter symbol specifies the general type of data, the second letter further specifically defines the data type, and the five numeric digits are the defined data.

As an example, consider that some investigator, in addition to reporting total catch, also reported the results as 23.1 fish per trawl. This second set of data would be entered in the data base via the Alpha Codes as follows:

o	First letter -- "A"	Indicates this entry is a measure of sample size.
o	Second letter -- "N"	Indicates the sample size entry is in units of per trawl.
o	The 5 numeric entries	023.1 note that the decimal point occupies one of the 5 numeric spaces.

The complete Alpha Code for this entry would be "AN023.1" and would be so entered on the encoding sheet. In the course of the study, seven major (or first letter) categories were identified. These seven categories and their 26 subcategories are listed on the following pages.

ACCESSION CODE

The accession code numbers are in the range of 000,001 through 899,999 and are assigned to all documents containing fish-temperature data or ancillary information used in the study. The inclusion of these numbers on the J-data sheets (and in the corresponding computer record) allows the user to retrieve original data documents for each station defined in the data base.

The special event codes are in the range 900,000 through 999,999 and are used to reference physical or functional changes in the station environment which could affect the use or interpretation of the encoded data. Examples of these special events are such occurrences as the construction dates for a local dam, major flood dates and resulting stream changes, man-made changes such as channelization and dredging. Additionally, biological information reported for a particular fish species or fish population, such as characteristic spawning behavior in a geographic region that may be different from other regions, is references via these codes. Pages 172-183 contain a complete list of the special codes used in the study to date.

ALPHA CODE

A	SAMPLE SIZE (FISH)
C	SAMPLE NUMBER
D	SAMPLE NUMBER
E	SPAWNING DATA
F	MIGRATION DATA
G	EMIGRATION DATA
H	TEMPERATURE DATA

A SAMPLE SIZE (FISH)

AA	per stream mile
AB	per acre
AC	per man hour
AD	per hour
AE	per day
AF	per week
AG	per month
AH	per year
AI	in percent of sample (catch)
AJ	per site observation
AK	in pounds (non-commercial)
AL	per net
AM	per season
AN	per trawl
AO	in pounds (commercial)
AP	in grams
AQ	in ounces
AR	per net day

C SAMPLE NUMBER

CA	number of fishermen
CB	number of electro-shocking stations
CC	number of gill-nets
CD	number of traps
CE	number of weirs
CF	number of stream miles
CG	number of acres
CH	number of hours

CI	number of days
CJ	number of weeks
CK	number of months
CL	number of years
CM	number of angling trips
CN	number of trap nets
CO	number of trawls
CP	number of hours per trip
CQ	number of hours per acre
CR	number of seines
CS	number of fyke nets
CT	number of lifts
CU	number of young of year
CV	number of nets
CW	number of net-feet
CX	number of shocking samples
CY	number of downstream migrants
CZ	number of net days

D SAMPLE NUMBER

DA	number of samples
DB	number of pounds

E SPAWNING DATA

EA	minimum spawning temperature F°
EB	maximum spawning temperature F°
EC	optimum spawning temperature F°
ED	month of peak spawning
EE	day of peak spawning
EF	spawning at water temperature from __ to __ C°

EG	spawning at water temperature from__to__F^{o}
EH	minimum spawning temperature C^{o}
EI	maximum spawning temperature C^{o}
EJ	optimum spawning temperature C^{o}
EK	onset spawning temperature C^{o}
EL	spawn at water temperature C^{o}
EM	peak spawning at water temperature C^{o}
EN	peak spawning at water temperature F^{o}
EO	most spawning above C^{o}
EP	onset spawning temperature F^{o}
EQ	spawn at water temperature F^{o}
ER	most spawning above F^{o}
ES	peak spawning at temperature below C^{o}
ET	ending spawning temperature F^{o}
EU	preferred spawning period from mo/day
EV	preferred spawning period to mo/day
EW	temp range during preferred spawning period from__to__F^{o}
EX	peak spawning from mo/day
EY	peak spawning to mo/day
EZ	mean spawning temperature F^{o}

F MIGRATION DATA

FA	month of peak migration
FB	day of peak migration
FC	peak migration from month to month
FD	adult migration to spawning grounds from month to month
FE	juvenile migration from nursery area from month to month
FF	month/day juveniles begin migrating
FG	migration from month to month

FH	peak migration from mo/day
FI	peak migration to mo/day
FJ	temperature at migration from__to__F°
FK	mean temperature during migration peak F°
FL	spawning migration from mo/day
FM	spawning migration to mo/day
FN	temperature range during migration from__to__F°
FO	temperature at initiation of migration F°
FP	migration from mo/day
FQ	migration to mo/day

G EMIGRATION DATA

GA	peak emigration from month to month
GB	juvenile emigration from month to month
GC	mo/day of peak juvenile emigration
GD	juvenile emigration from mo/day
GE	juvenile emigration to mo/day
GF	smolt emigration from month to month
GG	peak emigration from mo/day
GH	peak emigration to mo/day
GI	mo/day of peak emigration
GJ	emigration from mo/day
GK	emigration to mo/day

H TEMPERATURE DATA

HA	temp range for designated depth from__to__F°
HB	temp range for designated depth from__to__C°

SPECIAL CODE ACCESSION SERIES

900,000	MISCELLANEOUS
901,000	FLOOD
902,000	POISON
903,000	DRAINAGE
904,000	FISH/TEMP RELATIONSHIP
905,000	CATCH RATE DATA
906,000	TEMPERATURE

900,000 MISCELLANEOUS

900,000 Miscellaneous-Murphy Flowage, Wisconsin
Pan Fish Removal Program - May 22 to June 22, 1961 - To study the effect of fish removed on the remaining population.

900,001 Miscellaneous-Escanaba Lake, Wisconsin
Calibration error for week of June 15, 1970.

900,002 Miscellaneous-Escanaba Lake, Wisconsin
(Minimum and Maximum 1962-1969) Water temperatures taken from Taylor thermograph records which were returned to Wisconsin without keeping a copy.

900,003 Miscellaneous-Pigeon River, Michigan (1959)
"One contributing cause of decline in catch was the work that the Lake and Stream Improvement Section of the Fish Division was doing."

900,004 Miscellaneous-Wheeler Reservoir Browns Ferry Plant-River Mile 293
"Two changes appear to be of greatest significance...; the almost complete elimination of skipjack herring from the catch and the increased number of species and total catch of game fish. These changes appear to be reflections of the changed habitat due to construction activities at Browns Ferry."

900,005 Miscellaneous-Barren River Reservoir, Kentucky
Creel Census per month from March to October, 1968, is an estimate based on actual count.

900,006 Miscellaneous-Nolin River Reservoir, Kentucky
Creel Census per month from March to October, 1968, is an estimate based on actual count.

900,007 Miscellaneous-Bull Shoals Lake, Arkansas
Any spawning data utilized or made public from this station (reference source 710919) must refer to Mr. Lou Vogele, National Reservoir Research Program, Division of Fisheries Research, Bureau of Sport Fisheries and Wildlife, Fayetteville, Arkansas.

900,008 Miscellaneous-Lake Pend Oreille, Idaho
"The 1951 to 1954 harvest would come from fish spawned before dam construction, the 1955 to 1958 harvest from fish spawned after."

900,009	Miscellaneous-Lake Pend Oreille, Idaho Creel Census - 1953 - adjusted for missed fisherman Creel Census - 1951, 1954-1957, 1963-1964, 1966-1967 - preliminary estimates
900,010	Miscellaneous-Big Springs Creek, Idaho The rainbow trout counts are "fish which could have been resident rainbow trout and/or steelhead trout".
900,011	Miscellaneous-Big Springs Creek, Idaho Trapping counts for Brook trout and Chinook salmon for the years 1962-1965 are estimates.
900,012	Miscellaneous-Moosehead Lake, Maine Creel Census - 1967-1970 estimated from expanded samples.
900,013	Miscellaneous-Lake Griffin, Florida Creel Census - 1968-1969 are estimates.
900,014	Miscellaneous-Walker Lake, Nevada Catch composition from 57 gill net sets was 4652 fish from 1954-1958.
900,015	Miscellaneous-Walker Lake, Nevada Depth-temperature values from 4 year seasonal water temperature average.
900,016	Miscellaneous-Topaz Reservoir, Nevada Temperature profiles are 1954-1958 average quarterly extremes.
900,017	Miscellaneous-Pyramid Lake, Nevada Temperatures for 1958 are average monthly seasonal temps for 1954-1958.
900,018	Miscellaneous-Utah Lake, Utah Temperatures for 1939 are actually mean monthly temperatures over a ten year period from 1929-1939.
900,019	Miscellaneous-Maybeso Creek, Alaska Before logging-1950-1952 During logging-1953-1957 After logging-1958-1962
900,020	Miscellaneous-Maybeso Creek, Alaska Fish counts are estimated from aerial and foot surveys.
900,021	Miscellaneous-Harris River, Alaska Before logging-1953-1958 During logging-1959-1961 After logging-1962
900,022	Miscellaneous-Harris River, Alaska Fish counts are estimates from aerial and foot surveys.
900,023	Miscellaneous-Indian Creek, Alaska Fish counts from estimates of aerial and foot surveys.
900,024	Miscellaneous-Savage River Reservoir, Maryland Creel Census dated September 30, 1958 is actually from May 1, 1958 to September 30, 1958. It is an estimate.
900,025	Miscellaneous-Little Patuxent River, Maryland Creel Census dated October 1958 is actually for April 1958 through October 1958.
900,026	Miscellaneous-Cottonwood Creek, Alaska Salmon counts (weir) are estimates for 1956 and 1957.
900,027	Miscellaneous-Two Buttes Reservoir, Colorado Seine hauls for 1951 are estimates based on actual counts.

900,028 Miscellaneous-Tenkiller Ferry Reservoir, Oklahoma

August 1960 and June 1966 poison counts are estimates based on actual count. (Rotenone samples).

900,029 Miscellaneous-Keystone Reservoir, Oklahoma

The 1960 fish counts (method - combination) are from the Arkansas River and the Cimmaron River. They are pre-impoundment studies. "The Keystone Dam will be constructed approximately one mile below the confluence of the Arkansas and Cimarron River, Tulsa County, near the community of Keystone, and the reservoir will extend into five counties, Tulsa, Osage, Payne, Creek, and Pawnee." The reservoir "will extend upstream for 30 miles on the Arkansas River and 32 miles on the Cimarron River". The reservoir was completed February 1964.

900,030 Miscellaneous-Keystone Reservoir, Oklahoma

The June 8, 1966 poison counts are estimates based on actual count. (Rotenone)

900,031 Miscellaneous-Missouri River at Fort Calhoun, Nebraska

The fish counts for 1971 are seasonal counts. April represents spring, June represents summer, and September represents fall.

900,032 Miscellaneous-Missouri River at Brownville, Nebraska

The fish counts for 1971 are seasonal counts. April represents spring, June represents summer, and September represents fall.

900,033 Miscellaneous-High Rock Lake, North Carolina

Seining count for September 9, 1960 is actually for November 5, 1959 to September 9, 1960.

900,034 Miscellaneous-Lake Travis, Texas

Creel Census for July 1953 is actually for June and July 1953. All temperatures were taken from a Bathythermograph.

900,035 Miscellaneous-San Angelo Reservoir, Texas

Creel Census for 1956 is actually for September 1954 through April 1956.

900,036 Miscellaneous-Ship Creek near Anchorage, Alaska

There are 3 Power Plants using cooling water from Ship Creek. There are Chugach Electric Association, 1 mile above mouth of creek, West Elm Dorf, 3.6 miles above mouth, and Fort Richardson, 8.2 miles above mouth. All water temps were taken at 9 stations from mouth to City of Anchorage Dam, 11.5 miles above mouth.

900,037 Miscellaneous-Hood Bay Creek, Alaska

Downstream outmigrant counts are for Dolly Varden, Pink Salmon, Chum Salmon and Coho Salmon smolts only. Inmigrants leave the creek the same year as entry and consist of spawned-out and nonspawning char; Therefore these outmigrants were not encoded. Inmigrant counts for this station include estimates by Alaska Fish and Game personnel.

900,038 Miscellaneous-Eva Creek, Baranof Island, Alaska

"Actual spawning of Dolly Varden chars was not observed in the Lake Eva system. During October many upstream migrating Dolly Varden passing the weir were found upon examination to be spawned out. Since little spawning area is available below the weir, the possibility exists that these fish spawned in other systems, dropped back down to salt water and then migrated on up to Lake Eva for the winter."

900,039 Miscellaneous-New Creek Lake, West Virginia

All species caught by gill net on July 30, 1969 were caught at a depth range of 0 - 30 feet. All species caught by gill net on August 7, 1969 were caught at a depth range of 20 - 30 feet.

900,040 Miscellaneous-Russian River, Kenai Peninsula, Alaska

All Creel Census are estimates based on actual counts.

900,041 Miscellaneous-More Trout, Inc. Pond (MTI), Michigan
Dip net data for 1961 is and "estimate based on data from previous years' recovery averages at MTI and Guiley ponds."

900,042 Miscellaneous-Fire Creek Weir below Lower Fire Lake, Alaska
Upstream inmigrant counts for Dolly Varden, Rainbow trout and Coho Salmon smolts are encoded.

900,043 Miscellaneous-Fire Creek Weir below Lower Fire Lake, Alaska
"The March 27 earthquake severely damaged the upstream-downstream control structure on Lower Fire Lake. Reconstruction of this facility was started on June 22 and completed on August 14, 1964. The traps at the Fire Lake Hatchery were put into operation on May 15, and 15 adult rainbow trout were captured. Because the traps on Lower Fire Lake were inoperative during the peak of the coho salmon and rainbow trout out-migration, little data was obtained on migratory habits.

900,044 Miscellaneous-Alaska
The Creel Census for the following years and stations are estimates based on actual count:
1955-Russian River
1954-1955-Anchor River, Kenai Peninsula
1955-Deep Creek, Kenai Peninsula
1955-Stariski Creek, Kenai Peninsula
1955-Quartz Creek, Kenai Peninsula
1955-Crescent Creek, Kenai Peninsula
1955-Cooper Creek, Kenai Peninsula
1952, 1955-Hidden Lake, Kenai Peninsula
1955-Big Lake

900,045 Miscellaneous-Mississippi River at Hickman, KY: at Tunica, MS: at Vicksburg, MS: at Tarbert Landing, LA: at Luling, LA. Atchafalaya River at Simmesport, LA.
"Endrin was the agent responsible for catastrophic fish kills in the Lower Mississippi River Basin in 1963-1964."
"Endrin present in the Mississippi and Atchafalya Rivers, and the rate of production and use, declined after this time to a level where endrin was no longer a pollution hazard."
"At the present rate and methods of production, waste disposal, and use, concentrations of endrin in the waters of the Lower Mississippi River Basin may be expected to remain at levels not harmful to fish."

900,046 Miscellaneous-Spring Bayou, Louisiana and Amite River, Louisiana
Poison counts (Rotenone) for August 1962 are actually for the summer of 1962.

900,047 Miscellaneous-Lac Des Allemands, Louisiana
"The most marked changes in water chemistries from Lac Des Allemands occurred in samples taken September 20, 1965, ten days following Hurricane Betsy.... Heavy rains and large amounts of foliage and debris fell into the lake and bayous and canals, but more restricted to areas in Lac Des Allemands where these bayous entered."

900,048 Miscellaneous-Oahe Reservoir, South Dakota
Annual creel census for 1960 is actually July, 1959 to March, 1960.
Annual creel census for 1961 is actually April, 1960 to March, 1961.
Water temperatures were taken from June 22, 1959 to September 7, 1959 and from June 13, 1961 to August 22, 1961.

900,049 Miscellaneous-Little Red River near Pangburn, Arkansas and near West Point, Arkansas

Hydro-Electric Power Generation at Greers Ferry Dam began on June 9, 1964. Greers Ferry Dam is located at River Mile 79.0, the Pangburn station about River Mile 60 and the West Point station within 16 miles of the confluence with the White River.

"Since the Greers Ferry Dam has been discharging cold water into this river, a put-and-take trout fishery has existed as far down stream as Pangburn. All native warm water fish species have been eliminated. From Pangburn to the mouth of the river, below West Point, only a remenant stock of native fishes has survived." (Personal communication with Mr. Bill Keith, Arkansas Game and Fish Commission, Little Rock, Arkansas.)

900,050 Miscellaneous-Tchefuncte River near Covington, Louisiana

The fish counts for 1967 are actually for September, 1966 to January, 1968. The fish counts are seasonal counts. March represents winter, April represents spring, June represents summer, and October represents fall.

900,051 Miscellaneous-Licking River near Butler, near Kentontown and near Blue Lick Springs, Kentucky

Temperature data for these three stations is located at McKinneysburg, Kentucky. (Latitude 38°35'52 and Longitude 84°16'00) The same temperature data was used for all three stations.

900,052 Miscellaneous-Licking River near West Liberty and near Swampton, Kentucky

Temperature data for these two stations is located at Farmers, Kentucky. (Latitude 38°08'24 and Longitude 83°33'26) The same temperature data was used for both stations.

900,053 Miscellaneous-Big Flatbrook River, New Jersey

Eight stations were encoded on the Big Flatbrook River. Since water temperature data was only available for two of these stations (330101 and 330103), the water temperatures were also encoded in the stations in close proximity.

Water temperatures for station 330101 were also used for stations 330100 and 330102. Water temperatures for station 330103 were also used for stations 330104, 330105, 330106, and 330107.

900,054 Miscellaneous-Elk River, Tennessee

There are three Elk River stations. When the available data was not separated by stations but combined into one total count for the whole river, we input this combined data into all three stations (470401, 470402, and 470403).

The combined data put into all three stations was electro counts for 1963 and 1965, and creel counts for 1962 through 1965.

(The creel count for 1965 is an estimate.)

900,055 Miscellaneous-South Fork Elkhorn Creek, Kentucky

The South Fork Elkhorn Creek near Paynes, Kentucky is polluted with municipal sewage below the Town Branch Creek.

The South Fork Elkhorn Creek near Faywood, Kentucky is the only unpolluted station on the South Fork.

900,056 Miscellaneous-South Fork Elkhorn River near Faywood, Kentucky

Electro counts for 1960-1961, 1969 are number of fish per acre.

The temperatures for 1968-1970 were recorded with mercury and alcohol stream thermometers.

900,057 Miscellaneous-South Fork Elkhorn River near Paynes, Kentucky

Electro counts for 1960-1965, 1969 are number of fish per acre.

The water temperatures for 1968-1970 were recorded with mercury and alcohol stream thermometers.

900,058 Miscellaneous-North Fork Elkhorn Creek near Georgetown, Kentucky

The water temperatures for 1968-1970 were recorded with mercury and alcohol stream thermometers.

October, 1968-Electro counts--When raw data listed a fish count as tr. (trace), we designated trace to mean 1 fish captured. We did this to show this fish was present.

900,059 Miscellaneous-Main Elkhorn Creek near Frankfort, Kentucky
The water temperatures for 1969-1970 were recorded with mercury and alcohol stream thermometers.

900,060 Miscellaneous-Mississippi River from Grand Rapids to Brainard, Minnesota
The trap net counts dated September, 1967 are actually for September, 1967 and August and September, 1965.

900,061 Miscellaneous-Mississippi River, Pool 13 and Pool 26
The creel census for 1962 is seasonal. May represents spring, July represents summer, and September represents fall.

900,062 Miscellaneous-Mississippi River at Dubuque, Iowa
All spawning data for this station applies to all of the upper Mississippi River stations. (Pools 3 through 26B)

901,000 FLOOD

901,000 Flood-Lawrence Creek, Wisconsin
Flood-Spring 1960
Flood-February 9, 1966 - damaged brook trout redds.

901,001 Flood-Bohemian Valley Creek, Wisconsin
Single run shocking data prior to (April 13, 1959) and after (May 25, 1959) a flash flood.

901,002 Flood-Pigeon River, Michigan
Flood-May 1957-catch of wild trout smallest since the establishment of the Pigeon River Station in 1949.

901,003 Flood-Apalachicola River, Florida
"Early in 1960, the Apalachicola River valley experienced the worst flood in many years. It began in the late winter and lasted until the approximate time for the striped bass to begin spawning.... It is believed that a major portion of the striped bass from the Apalachicola River went throuth the dam and into the Flint and Chattahoochee Rivers to spawn."

901,004 Flood-Feather River Hatchery, California
The hatchery is located upstream from Oroville-Chico Highway Bridge. Below dam sight, the river flooded from December 21, 1964 to January 30, 1965. The hatchery facilities were damaged.

901,005 Flood-Sagehen Creek, California
In December 1955 "was the most severe flood of the study period and was followed by extreme low numbers of most fishes in 1956".

901,006 Flood-Lake Corpus Christi, Texas
In 1958 "during the last of February and the first of March a flood occurred" on Lake Corpus Christi.

902,000 POISON

902,000 Poison-Argyle Lake, Illinois
The lake was treated with antimycin on June 10, 1970.

902,001 Poison-Wheeler Reservoir, Alabama
The reservoir was treated with rotenone August and September 1970. Information listed as poison for September 1970 is for the whole reservoir (stations 010100 and 010102) not just one station (010101).

902,002 Poison-Anderson Ranch Reservoir, Idaho
The reservoir was treated with rotenone July 19 to August 11, 1965, July 25 to August 4, 1966 and August 9 to August 16, 1967. The shoreline was treated with rotenone to kill squawfish fry.

902,003 Poison-Bentsen State Park Lake, Texas
"This lake was treated with rotenone in January, 1960, to eradicate the existing fish population and restocked with black bass (Largemouth bass) in March."
"In view of the fish collections (April and October 1961-gill nets), it is clear that the benefits obtained from the fish eradication in January 1960 have been nullified."

902,004 Poison-Buchanan Lake, Texas
Treated with rotenone January 25, 1956. "It is believed that a complete kill was achieved, but few fishes were taken."

902,005 Poison-Murvaul Bayou Reservoir, Texas
"Prior to impoundment, on September 17, 1957, about a twelve mile stretch of Marvaul Bayou above the dam was treated with Pro-Noxfish and rotenone powder to eliminate as nearly as possible the existing fish population."

902,006 Poison-Possum Kingdon Lake, Texas
Rotenone was applied to the lake on September 22, 1959. Gill net data for September 1959 was gathered before and after the treatment.

902,007 Poison-Bear Creek, Alaska
In 1963 a barrier was constructed at the outlet of Bear Lake and the lake was treated with rotenone inorder to eliminate competitor species of Silver Salmon. A total kill of Threespine stickleback, Sculpins, Dolly Varden, Red and Silver Salmon occurred. "The barrier at the outlet of rehabilitated Bear Lake was destroyed as a result of the Good Friday earthquake and reinfestation of the lake by Dolly Varden and Threespine sticklebacks occurred."

903,000 DRAINAGE

903,000 Drainage-Argyle Lake, Illinois
On September 7, 1970 the lake was drained before rehabilitation.

903,001 Drainage-Castleman Run Lake, West Virginia
"The lake was drained October 20-24, 1969."

903,002 Drainage-Burches Run Lake, West Virginia
"The lake was drained November 3-7, 1969."

903,003 Drainage-Sleepy Creek Lake, West Virginia
The lake "was drained during November, 1970, in order to make repairs to the drop inlet."

904,000 FISH/TEMP RELATIONSHIP

904,000 Fish/Temp Relationship-Murphy Flowage, Wisconsin
"Several fishery workers have found that growth initiation each year for warm water species is closely related to the time surface water temperature reaches 60°F." (Study period from 1955 through 1963)

904,001 Fish/Temp Relationship-Trout Lake, Wisconsin
Lake trout-"Preferred temperature is about 50°F. and they seldom remain for extended periods of time in warmer waters than 65°F. The siscower probably never gets in waters exceeding 40°F."

904,002 Fish/Temp Relationship-Murphy Flowage, Wisconsin
"Bluegills will tolerate quite warm water. The maximum lethal temperature tolerated is probably similiar to that of pumpkinseed sunfish and largemouth bass, namely 95°F."

904,003 Fish/Temp Relationship-Murphy Flowage, Wisconsin
Bluegill-"Food consumption is regulated by water temperature and decreases drastically below temperatures of 50°-55°F."

904,004 Fish/Temp Relationship-Lake Pend Oreille, Idaho
"The amount of time required for kokanee eggs to hatch and fry to emerge from the nests is governed by temperature. Within the range of 35 to 60 degrees F., the rate of development varies directly with the temperature.... Development is retarded by colder temperatures...."

904,005 Fish/Temp Relationship-Lake Mendota, Wisconsin
Yellow Perch-"Maximum temperatures tolerated in laboratory experiments was 92.0°F. Perch seem to prefer a water temperature of 69.8°F."

904,006 Fish/Temp Relationship-Brule River, Wisconsin
"Brown trout are most active and growth is best when water temperatures range between 65° and 75° F., although this species has tolerated water temperatures up to 81°F. for short periods."

904,007 Fish/Temp Relationship-Escanaba Lake, Wisconsin
Muskellunge-"Feeding drops off in water temperatures above 85°F." "Cool water temperatures are preferred, ranging from 33° to 78° F., but muskellunge can withstand temperatures up to 90°F. for short periods."

904,008 Fish/Temp Relationship-Lake George Northern Pike Slough, Minnesota
"It would appear from these observations that water temperatures in the middle 50's are necessary for spawning to occur." (Species-Northern Pike)

904,009 Fish/Temp Relationship-Murphy Flowage, Wisconsin
"Bass will tolerate temperatures of 80-90°F. Their lethal temperature is 96.8°F. Growth ceases at temperatures below 50°F."

904,010 Fish/Temp Relationship-Nanticoke River, Maryland
"The 1963 data show three spawning peaks correlated with rising water temperatures, and two depressions in number of eggs correlated with falling temperatures."

904,011 Fish/Temp Relationship-West Beaver Creek, Colorado
"The main factor that seemed to increase the number of fish trapped daily was maximum stream water temperature, especially when the daily increase was quite marked."

904,012 Fish/Temp Relationship-Lake Carl Blackwell, Oklahoma, Canton Reservoir, Oklahoma, and Buncombe Creek Arm-Lake Texoma, Oklahoma and Texas
"Loomis and Irwin (1954) found that depth distribution of fishes in Lake Carl Blackwell, Oklahoma, was not related to temperature, since temperature conditions were uniform. Hancock (1954) established that warm water entering the Canton Reservoir, Oklahoma, caused large fish aggregations which resulted in increased winter angling yields. Grinstead (1965) found that light penetration and turbidity influenced white crappie distribution more than any other physicochemical factor in Buncombe Creek, Lake Texoma, Oklahoma." (Quote taken from report #722212)

904,013 Fish/Temp Relationship-Canton Reservoir, Oklahoma
"In Canton Reservoir, Oklahoma, Hancock (1954) has shown that during the winter white crappie will aggregate in a locality with a higher water temperature if this is available. He found white crappie concentrated in tremendous numbers in a small cove which was being fed by warmer ground water. Hancock experimentally duplicated this condition in another small cove and observed a similar concentration where one did not exist prior to experimentation. This clearly irrustrates the fact that white crappie will select an area with a more desirable temperature if this is available." (Quote taken from report #722213)

904,014 Fish/Temp Relationship-Buncombe Creek Arm-Lake Texoma, Texas and Oklahoma
"Thermal stratification with a wide temperature range is only occasionally observed....Since there was for the most part no appreciable vertical temperature gradient, the recorded vertical movements of the white crappie cannot be interpreted as an attempt to move to more desirable temperature conditions. It was concluded, therefore, that factors other than temperature must have influenced the vertical distribution of the white crappie." "White crappie did appear to be influenced by light penetration, generally they occurred at a greater depth when the turbidity was low and nearer the surface as turbidity increased." (Quote taken from report #722213)

904,015 Fish/Temp Relationship-Buchanan Lake, Texas
"During the months of October and November (1955) the number of individuals (fish) taken in seines dropped sharply. This decline is probably due to the sharp decline in water temperatures and the resulting regression of shallow water aquatic vegetation which provided some cover."

904,016 Fish/Temp Relationship-Bear Creek, Alaska
"Various workers on red salmon investigations have noted that seaward migration followed shortly after breakup of lake ice and that cessation of seaward migration has been related to increasing minimum water temperatures usually about 50°F." "Downstream movement of silver salmon did not begin until the ice had broken up and the water reached 39.5°F. Ninety percent of the migration occurred between 41 and 56°F. This suggests silver salmon may have greater temperature tolerance limits than red salmon, whose migration is usually terminated at 50°F."

904,017 Fish/Temp Relationship-East Finger Lake, Kenai Peninsula, Alaska
"Water temperature appears to be the factor that exerts the most influence on the depth-distribution of Arctic char. Char were captured in water temperatures varying from 40° to 60° F. However, more than 89 percent were taken in water colder than 55°F. During July and August, 70 percent of the char were captured in water that ranged from 41° to 50° F. These data suggest that surface temperatures in excess of 55°F. tend to restrict Arctic char to mid-water (20-30 feet) or bottom depths (35-45 feet)."

904,018 Fish/Temp Relationship-South Fork Anchor River, Kenai Peninsula, Alaska
"Other studies and Alaskan observations have shown that the steelhead habit is to ascend the streams in the fall, winter over in the larger stream or lake areas, and spawn in the streams in the spring (when water temperatures are from 39-42°), followed by downstream migration to salt water."

904,019 Fish/Temp Relationship-Lake Catherine, Steam Plant Bay, Arkansas
Temp and fish collections were made in the cooling pond adjacent to the main body of the lake. Temps for 1967 are also available.
"There was and obvious seasonal ingress and egress of fishes within the effluent receiving bay."
"A direct correlation could not be made between the distribution of fishes in the effluent receiving bay and water temperatures. The average temperature in the plant bay in the summer of 1970 was very near the optimum temperature for most of the native warmwater species of fish in Lake Catherine."
"The concentration of fishes during winter months is brought on by an abundance of threadfin shad which seek out the warm water discharge. The concentrations of shad attract predator fishes into the area and create an excellent winter fishery."
"Other than food supply, dissolved oxygen concentrations was the major factor controlling abundance of fishes within the receiving embayment."

905,000 CATCH RATE DATA

905,000 Catch Rate Data-Canton Reservoir, Oklahoma
1950, 52-54, 60-61, 65--Creel Census are percentages
1964-67--Trawl counts are catch per haul
1964-65--Seine counts are catch per haul
1965--Meter net counts are catch per haul
1965-67--Poison counts are catch per acre (These are Rotenone Samples)

905,001 Catch Rate Data-Two Buttes Reservoir, Colorado
1946-52--Creel Census are percentages

905,002 Catch Rate Data-Summerville Reservoir, West Virginia
1966-67,70--Poison counts are percentages

905,003 Catch Rate Data-Sutton Reservoir, West Virginia
1966-67,70--Poison counts are percentages

905,004 Catch Rate Data-Burches Run Lake, West Virginia
Oct. 13, 1963--Poison counts are number of fish per acre
Oct. 16, 1967--Poison counts are number of fish per acre
Aug. 15, 1968--Poison counts are number of fish per acre
Nov. 11, 1969--Poison counts are number of fish per acre

905,005 Catch Rate Data-Conaway Run Lake, West Virginia
July 28, 1966--method "Not Given"--counts are number of fish per acre
July 26, 1967--Poison counts are number of fish per acre
July 11, 1968--Poison counts are number of fish per acre
July 9, 1969--Poison counts are number of fish per acre
May 29, 1970--Poison counts are number of fish per acre

905,006 Catch Rate Data-New Creek Lake, West Virginia
Sept. 7, 1966--method "Not Given"--counts are number of fish per acre
Sept. 11, 1967--Poison counts are number of fish per acre
July 18, 1969--Poison counts are number of fish per acre
July 29, 1969--Poison counts are number of fish per acre
Aug. 12, 1970--Poison counts are number of fish per acre

905,007 Catch Rate Data-Warden Lake, West Virginia
Sept. 6, 1966--Poison counts are number of fish per acre
July 27, 1967--Poison counts are number of fish per acre
July 24, 1968--Poison counts are number of fish per acre
Aug. 15, 1969--Poison counts are number of fish per acre
Aug. 24, 1970--Poison counts are number of fish per acre

905,008 Catch Rate Data - Sleepy Creek Lake, West Virginia
Sept. 22, 1966--Poison counts are number of fish per acre
Aug. 29, 1967--Poison counts are number of fish per acre
Aug. 14, 1969--Poison counts are number of fish per acre
Aug. 20, 1970--Poison counts are number of fish per acre
Nov. 25, 1970--Poison counts are number of fish per acre

905,009 Catch Rate Data-Catlemans Run Lake, West Virginia
Oct. 5, 1967--Poison counts are number of fish per acre
Aug. 12, 1968--Poison counts are number of fish per acre
Aug. 11, 1969--Poison counts are number of fish per acre

905,010 Catch Rate Data-Bear Lake, West Virginia
Sept. 11, 1967--Poison counts are number of fish per acre

905,011 Catch Rate Data-Baker Lake, West Virginia
Aug. 29, 1967--Poison counts are number of fish per acre

905,012 Catch Rate Data-Teter Creek Lake, West Virginia
Sept. 2, 1967--Poison counts are number of fish per acre
Aug. 29, 1968--Poison counts are number of fish per acre
Sept. 1969--Poison counts are number of fish per acre
Aug. 24, 1970--Poison counts are number of fish per acre

905,013 Catch Rate Data-Laurel Lake, West Virginia
Oct. 3, 1967--Poison counts are number of fish per acre
Aug. 1968--Poison counts are number of fish per acre
Aug. 28, 1969--Poison counts are number of fish per acre
Sept. 16, 1970--Poison counts are number of fish per acre

905,014 Catch Rate Data-Bonds Creek Lake, West Virginia
June 18, 1968--Poison counts are number of fish per acre
June 24, 1969--Poison counts are number of fish per acre
June 17, 1970--Poison counts are number of fish per acre

905,015 Catch Rate Data-Mississippi River
All combination fish counts are in pounds for the following stations along the Mississippi River--
Pools 3,4,4A,5,5A,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,24, 25,26, and 26B
Also stations--040900,161202,180500,200301,210100,260600,280500, and 470200

906,000 TEMPERATURE

906,000 Temperature-Fontana Reservoir, North Carolina
All data is for 1965

Species	Month	Temperature Range
037	05	70-73
	07	58-84
	10	70-71
032	05	64-76
	07	72-84
	10	69-72
042	05	57-75
	07	66-84
	10	71
035	05	67-77
	07	77-84
	10	70-71
039	05	73
	07	71-76
	10	71-72
031	05	61-76
	07	68-84
	10	71-72
109	05	65-72
	07	76-84
	10	72
022	05	70-76
	07	68-84
	10	73
003	05	62-76
	07	72-82
	10	71-73

906,001 Temperature-Lake Colorado City, Texas
"The intake temperatures are representative (within 1 to 3°F.) of 85% of the water in the entire reservoir."
(Source-Letter dated April 4, 1972 from John E. Tilton)

906,002 Temperature-Mountain Fork River below Broken Bow Reservoir, Oklahoma
Water temperatures fluctuated erratically due to Hydroelectric Power Generating station water releases from Broken Bow Reservoir.

APPENDIX E

MAIN SOURCES OF FISH-TEMPERATURE INFORMATION

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